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Technical Information

One of the surprises of this war is the dearth of technical queries. It may be that with so many foundries being engaged upon the production of munitions and receiving all the technical information they require from the Government departments, there has been a general lessening in demand. Moreover, where difficulties do arise, it is usual for the foundry executives personally to visit an establishment which has overcome them, for a first-hand inspection. Obviously no better method could be devised. Yet it is probable that such time-absorbing trips could be avoided if only persons experiencing technical troubles would address a letter to the appropriate development bureau. The Government departments recognise the great utility of these organisations, and do not hesitate to make use of their services.

It seems desirable to recall that the technical bureaux, often staffed with experts of international reputation, now cover the fields of nickel, copper, aluminium, zinc, tin and lead. Conversations with prominent members of the staffs of these organisations reveal how they have been able to render various manufacturing processes really efficient, so contributing very materially to the war effort. In every case, however, there is a feeling that there must be many other concerns whose methods could be improved if only they would contact with the appropriate bureau. The situation has been well expressed in the latest bulletin of the Tin Research Association, of which the following is an abstract:—

"It is a commonplace in scientific and technical circles that the demand for such services has fallen even below peacetime levels, and in our contact with wartime industry up and down this country we meet many instances where expert advice would have saved time and money. In the case of a large manufacturer of radiators where a plant for the *hot-tinning of army utensils* was installed, the quality of the work was quite low, as the firm were unaware of the steps which should be taken to avoid excessive iron contamination in the tinning bath. In other cases rough coatings could have been avoided by correct cleaning and fluxing; and yellow stain obviated by controlling the temperature of the final oil dip.

"The electro-deposition of tin, although now being worked satisfactorily in some shops, has many pitfalls, chiefly because the early processes were far from reliable. We still meet the men who 'know all about electro-tinning' and who 'get it done by the firm round the corner—but it all comes off on our hands.' A visit to the plating shop of one large concern which, incidentally, employs many hundreds of scientifically trained workers, showed that no effort had been made to control electro-deposition on modern lines. It was only a few hours' task to convert an unreliable and unsatisfactory process to the production of sound, smooth coatings of tin. In another case less than one-tenth of the supposed coating was being applied, for lack of control technique which has been known for years.

"The casting of special bronzes is a critical operation which profoundly affects the success of subsequent operations. We have met cases where melting conditions, methods of adding the alloying metals, rates of pouring, etc., have been far below the standards attained by experts in these fields.

"While recognising the pressure under which managements are now working, we submit that the technical executive's most important contribution to the efficiency of his organisation is to make sure that his problems are submitted to those specialists whose equipment and experience have been devoted to their solution."

Moreover, the Government-aided Research Associations are willing and eager to help with technical problems, even though it means temporarily taking men away from actual research. The annual report of the British Cast Iron Research Association discloses a good deal of extra work in this direction, but, glare reduction from furnaces apart, it is not on the scale one would have expected during war conditions.

If any of our readers are encountering difficulties of a nature which can be disclosed—and most of them usually enter this class—we will either through our own experts or through some other appropriate channel see that such problems are intelligently studied and reasonable suggestions for their remedy promptly put forward.

Institute of British Foundrymen

ELECTION OF NEW MEMBERS

At a Council meeting of the Institute of British Foundrymen, held in Birmingham recently, 42 applicants were elected to the various grades of membership, as follow:—

As Members.

Thos. Beale, assistant foundry foreman, Millar's Machinery Company, Limited, Bishop's Stortford; W. L. Beresford, foundry executive, Stanton Ironworks Company, Limited, near Nottingham; G. E. Hider, senior partner, G. E. Hider & Son, Torquay; D. Jepson, Lecturer in Metallurgy, Bradford Technical College; H. Morton, ironfoundry manager, Lee, Howl & Company, Limited, Tipton; F. Oldershaw, foundry manager, E. Green & Son, Limited, Wakefield; F. W. Rose, foundry manager, Rose & Parkin, Leeds; J. M. Stones, workshops manager, Austral Ironworks, Johannesburg, S.A.; R. R. Taylor, ironfounder, Robt. Taylor & Company (Ironfounders), Limited, Larbert; A. Tipper, works chemist and metallurgist, Wilmot-Breeden, Limited, Birmingham; G. K. Walters, manager, Dorman, Long & Company, Limited; F. Wright, Director for Iron Castings, Ministry of Supply Iron and Steel Control; J. H. Wright, maintenance engineer, Amalgamated Press, Limited, London; and J. A. Wylde, assistant sales manager, Hale & Hale (Tipton), Limited, Dudley Port.

As Associate Members.

C. Bailey, foreman moulder, J. Evans & Sons, Limited, Wolverhampton; R. Bales, Junior Technical School Master, Twickenham Technical College; S. Bullimore, assistant chemist, Ideal Boilers & Radiators, Limited, Hull; P. A. Davenport, foundry superintendent, Butterley Company, near Derby; G. Derrington, brass moulder, Albutt, Son & Jackson, Limited, Halifax; A. G. Evans, founder, H. M. Dockyard, North Devonport; H. I. Grant, works chemist, R. A. Lister & Company, Limited, Dursley; R. J. Green, assistant metallurgical chemist, R. A. Lister & Company, Limited; H. Hayden, wood patternmaker, Ley's Malleable Castings Company, Limited, Derby; S. Jones, chemist, English Electric Company, Limited, Bradford; D. I. Kidd, wood patternmaker, Wright, Boag & Company, Johannesburg, S.A.; W. McKerracher, machine-plate moulder, Metropolitan-Vickers Electrical Company, Limited, Manchester; E. Noad, patternmaker, S. Bayliss, Wednesbury; A. H. Normington, moulder, Rolls-Royce, Limited, Hillington; R. A. Partridge, moulder, H.M. Dockyard, Chatham; A. Smethurst, ironfoundry foreman, Lancaster & Tonge, Limited, Salford; J. D. Starkey, moulder, F. Parramore & Sons (1924), Limited, Chapeltown, Sheffield; W. Taylor, foreman moulder, T. Richards & Sons, Limited, Bristol; I. G. F. Walker, metallurgical chemist, Humber, Limited, Coventry; R. R. Watkins, production investigation and planning engineer, Gramophone Company, Limited, Hayes, Middlesex; J. H. West, engineering patternmaker, Eagle Brass & Iron Foundry, Johannesburg, S.A.; and W. W. Wright, moulder, Exchange Engineering Works, Wolhuter, S.A.

As Associates.

E. H. Beech, iron moulder, Thomas Ryder & Son, Limited, Bolton; H. W. Griffiths, foundry apprentice, English Electric Company, Limited, Bradford; H. Longmore, apprentice moulder, Steel, Peech & Tozer, Rotherham; and J. L. Younger, apprentice, R. A. Lister & Company.

As Associates (Students).

W. H. Hughes, apprentice moulder, Brown, Lenox & Company, Limited, Pontypridd, and A. Stuttard, apprentice foundry metallurgist, Walmsleys (Bury), Limited, Bury, Lancs.

British Cast Iron Research Association

ANNUAL GENERAL MEETING

The twentieth annual general meeting of the British Cast Iron Research Association was held on Wednesday, October 30, at the Queen's Hotel, Birmingham. Dr. J. E. Hurst presided. The business was of a formal character. The report of the Council, reviewing the work of the Association during the year ended June 30 last, together with the accounts, was adopted. The report was abstracted in last week's issue of the JOURNAL.

Election of Officers

Lord Austin was re-elected President, and the following were reappointed Vice-Presidents: Mr. J. F. Davies, Dr. W. H. Hatfield, F.R.S., Mr. V. Jobson and Mr. P. Pritchard.

The Council for the current year consists of P. A. Abernethy, C. W. Bigg, J. Cameron, J.P., E. W. Colbeck, F. J. Cook, E. C. Evans, H. Field, T. Firth, J. T. Goodwin, F. Horn, J. E. Hurst, G. T. Lunt, T. Makemson, G. Pate, O.B.E., A. J. Richman, W. Scott, A. W. Steven, J.P., W. Todd, Prof. T. Turner, and P. H. Wilson.

Messrs. Poppleton and Appleby were re-elected auditors.

Thanks were accorded to the Council and members of committees and sub-committees for their services during the year, to the staff, and to the chairman for presiding.

Higher Railway Charges

CONSULTATIVE COMMITTEE'S REPORT

The reasons prompting the Charges (Railway Control) Consultative Committee, under the chairmanship of Mr. Bruce Thomas, to recommend the additional increase in railway fares and charges to 16⅔ per cent. on pre-war rates are set out in a report issued as a White Paper.

In its report to the Minister of Transport the Consultative Committee states that the Railway Executive Committee, which manages the railways for the Government, in August applied for increased charges to yield by September 30, 1941, a sum, together with the 10 per cent. higher rates already in force, amounting to £44,500,000. This would have involved raising rates and fares by a further 6.8 per cent. and brought them to 17½ per cent. above pre-war level. The inquiry was protracted so that it was possible to obtain figures of the results of the operations during the first year of war. Based on these, it was shown that the increases in force and proposed would produce £46,824,000 instead of the £44,500,000 required. The percentage increase needed was therefore reduced from the proposed 17½ per cent. to about 16½ per cent.

Steel-Casting Design Film

A new sound slide film explaining all the known and tested principles of steel-casting design has been prepared by the Steel Founders' Society of America, 920, Midland Building, Cleveland, Ohio, for loan to interested organisations in the States, according to "The Iron Age."

Abrasive-Wheel Economy in Foundries

Instancing the efficient use of abrasive wheels, resulting from maintenance of the recommended peripheral speed, and correct selection of the grade of the wheel, Mr. W. Campbell-Pitt, in "Engineer and Foundryman" (South Africa) states that in several foundry dressing shops the stubs of 24-in. dia. wheels, instead of being discarded at 12 in., as was the old practice, are now used until a diameter of 4½ in. is reached. Even then the stub is not wasted, as it is broken up and used for hand-rubbing castings.

Random Shots

The reports of the annual outings of the various chapters of the American Foundrymen's Association read like a fairy tale at the present time to hard-working British foundrymen. They tell of picnics and excursions into the country, embellished with games, competitions and a spot of excellent victuals. The most popular competition seems to be horseshoe pitching (one would have imagined that motor tyres would have come more easily to hand in that land of automobiles). The soft ball game (slam bang) is a universal sport on such occasions, while the *pièce de résistance* for the table (or is it a cloth spread on the grass?) is undoubtedly chicken, be it *à la* Maryland or more ambitiously "barbecued."

* * *

Evidently the chicken in the States plays the same rôle as cold Scotch salmon does in summer festivities over here. At all events, it would be a strange and delightful picnic for anyone from this country, which was accompanied by chicken "barbecued" (roasted whole on a stick?) in the backwoods and corn husked and cooked on the spot!

* * *

It must not be imagined that there is any implication that it is all play and no work in the States. Anyone who has been there or is acquainted with any American business man is aware at what high pressure they can work at times, but that is just what is enviable about life over there just now. Good hard work is rewarded by pleasant relaxation. Here, the relaxation is missing!

* * *

Mrs. Malaprop took her dog with her to a knitting party the other day. As the dog became more and more restless, Mrs. Malaprop became more and more angry with it.

"If you don't keep still," said she at last in exasperation, "I'll give you a good whelping."

* * *

After the party she took the dog home, where it was greeted by the young daughter of the house.

"Come here, Gyp," ordered that young lady. Gyp did not come. "Come here, Gyp, inspontantaneously!" commanded that true daughter of a delightful Mrs. Malaprop.

* * *

The crossword clue of the week comes from the "Daily Telegraph."

Clue.—Once in a hospital this case is not likely to leave it.

Answer.—Stair.

"MARKSMAN."

Catalogues Received

Internal Transport. A four-page folder received from Mr. E. R. Briggs, 17, Lawford Road, Rugby, describes and illustrates a really ingenious new type of two-wheel lifting-platform hand truck. It is used in connection with stillages and is eminently suited for use in foundries, with which industry Mr. Briggs has for many years been associated. This pamphlet is available to our readers on writing to Rugby.

Automatic Temperature Control. A folder received from Bristol's Instrument Company, Limited, Brent Crescent, North Circular Road, West Twyford, London, N.W.10, not only illustrates and describes an important plant installed in a large steelworks for controlling the bright annealing of steel, but details the very considerable number of advantages the users found to result from the installation. The folder is available to our readers on writing to West Twyford.

Damping Capacity, Endurance, Electrical and Thermal Conductivities of Some Grey Cast Irons*

By C. H. LORIG and V. H. SCHNEE

The engineering properties of grey cast irons are commonly defined in terms of the ordinary static tests. The tensile strength, transverse strength, deflection and hardness, as determined by tests on standard specimens roughly corresponding to the actual casting sections, are usually considered sufficient for design purposes. In the development of new alloy irons, it is desirable to know the effect of additions of the alloying element on the less frequently determined properties of cast iron. The use of copper as an alloying element has, for example, resulted in many inquiries as to its effect on the thermal and electrical conductivities and the dynamic properties of cast iron. During the course of an extensive investigation of the use of copper in cast iron conducted at Battelle Memorial Institute by several of the large copper producers, attention has been given to the determination of these properties for a few copper alloy cast irons. It is the purpose of this Paper to add the results of these tests to the rather meagre data which are available in technical literature.

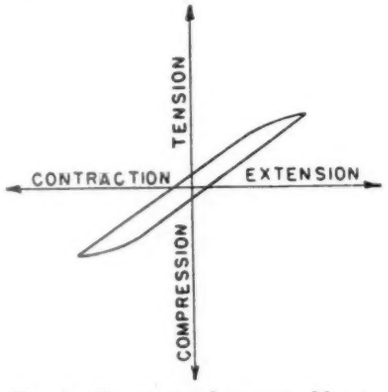

FIG. 1.—HYSTERESIS LOOP FOR METAL UNDER REVERSED STRESSES.

Damping Capacity of Copper Cast Irons

As pointed out in the discussion of damping in the symposium on cast iron,[1] it is not so commonly realised that the effective strength of a vibrating part may be made much greater if made with a material of high damping capacity and only fair strength than if made with a much stronger material lower in this property. MacKenzie[2] gives the damping capacity as the reason why grey cast irons are so successful in bedplates and frames for machines and vibrating machinery of all kinds.

Damping capacity has been defined as that property of a material which causes vibrations to die out. The classic example is that of a tuning fork; made of steel, the fork will vibrate for many seconds; made of cast iron, the vibrations will die out quickly; and if made of lead, the fork would vibrate hardly at all. In this series, lead is said to have the highest damping capacity and steel the lowest. The soft irons have high damping capacities, and in this respect are far superior to steel. As the strength, hardness and stiffness of the irons increase, the damping capacity is lowered, but even in the high-strength irons it is better than that of steel.

An explanation of the high damping capacity of grey cast irons involves a consideration of its elastic properties, its low modulus of elasticity, compared to that of steel, and its metallographic structure. Grey cast iron is not a truly elastic material. The stress-strain diagram, obtained in the tensile or transverse test, is curved from its origin, showing some degree of plastic deformation as stress is first applied. In cyclic loading, its stress-strain diagram, as sketched by Roberton,[3] is shown in Fig. 1.

The hysteresis loop represents the amount of energy absorbed during each stress cycle. The energy used to deform the metal is liberated as heat and causes a rise in temperature of the metal. An unlimited amount of energy can be dissipated without damage by a metal subjected to cycles of stress below its elastic limit. If the material were perfectly elastic between the limits of stress employed, this stress-strain diagram would be a straight line. There would be no hysteresis loop and the damping capacity would be zero. The existence of damping thus implies plastic deformation as the proportional limit of the material is exceeded. The damping capacity varies with the applied stress as well as with the elastic properties of the material. It may be measured as the ratio of plastic strain to elastic strain.

The low modulus of elasticity of cast iron relative to steel results in greater deformations in cast iron than in steel for equal stress concentrations. Cast iron behaves as a ductile rather than a brittle material in its ability to deform plastically under low stress. This permits the material to redistribute applied stresses and smooth out stress concentrations that might be serious in steel. It shows its plastic behaviour under just the conditions where plasticity is needed to prevent the building up of stress concentrations, that is, at low stresses. Ability to deform locally at low stresses, that is, a low proportional limit, seems to be one of the most important features of "crackless plasticity," the term used by Moore[4] to lump together the combination of properties accompanying low notch sensitivity.

The graphite particles present in grey cast iron have no mechanical strength. They act as tiny voids in the material which conceivably permit plastic deformation of the metal surrounding these voids at lower stress concentrations than would otherwise be the case. This contributes to the damping capacity of cast iron and helps to explain its low notch sensitivity as well.

The Wohler Institute, Germany, has been a centre of research for the investigation of the damping properties of materials. Foeppl[5] and von Heydekampf[6] have described the different methods that have been developed for the determination of damping capacity. This can be measured experimentally by static tests where the deformation produced by relatively small loads is accurately measured by temperature measurements in a test-piece under cyclic loading as in the fatigue test or by the energy absorbed by a fatigue specimen. The free vibration method described by Foeppl, and known in the United States as the Foeppl-Pertz test, has been adopted as somewhat of a standard for the investigation of damping. The apparatus has been described by Smalley[7] and Case.[8]

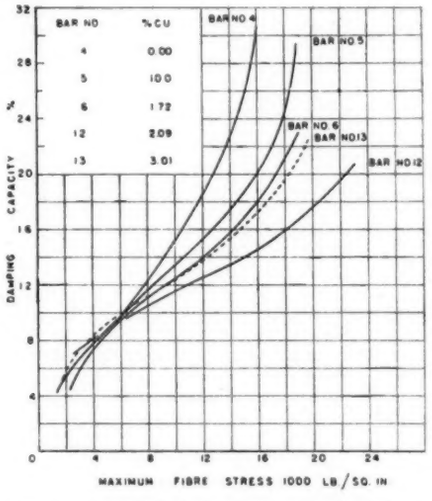

FIG. 2.—DAMPING CAPACITIES OF HIGH-CARBON COPPER CAST IRONS.

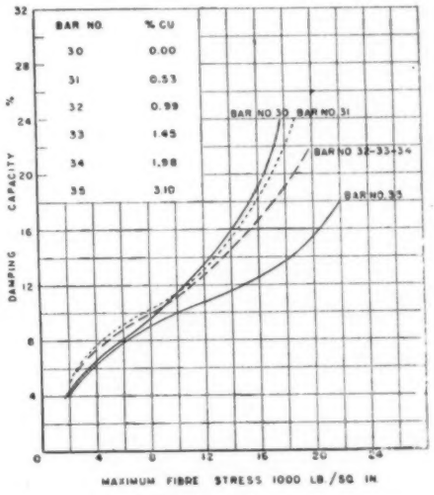

FIG. 3.—DAMPING CAPACITIES OF MEDIUM-CARBON COPPER CAST IRONS.

The per cent. damping capacity is calculated from the autographic curves. These calculations are tedious and the details of the method are not available in the literature. An article[13,14] describes a resonance method of determining damping coefficients recently developed in Germany. It is claimed that this method more nearly simulates the conditions encountered in crankshaft service than the free vibration method. The torsional damping coefficients obtained show that damping is from 80 to 120 per cent. greater with cast iron than with crankshaft steels. The damping coefficient, shown by this test, varies with the tensile strength and modulus of elasticity in about the same way as that obtained with other methods of testing.

Experimental Data

Sixteen cast irons were selected for the damping tests. These were taken from a number of experimental heats made in the indirect-arc furnace under carefully controlled conditions. All melts were heated to 1,540 deg. C. in the furnace, poured into ladles and held until the temperature had dropped to 1,400 deg. C. before casting into test-bars. Solid round specimens, of 0.50 in. dia. with an effective length of 7.31

* Paper presented to the annual convention of the American Foundrymen's Association in Chicago. The authors are with the Battelle Memorial Institute, Columbus, Ohio.

in., were machined from standard 1.2-in. transverse test-bars for use in the damping tests. The compositions and static properties of these irons are shown in Table I.

The per cent. damping capacity as calculated for different values for the maximum fibre strength are given in the original Paper. These data are taken from a single test of each iron, although actually from four to eight tests were made. Tests were begun at low maximum fibre stresses and the stress increased in each test. The average damping capacities for various maximum fibre stresses for each of the runs are summarised in Figs. 2, 3 and 4. It is evident that at low stresses, the irons differ very little in their damping capacities, but as the maximum fibre stress increases, the stronger, alloyed irons are lower in damping capacity than are the weaker irons of the different groups. The damping capacities of the cast irons were computed at maximum fibre stresses equal to 15 and 35 per cent. of the tensile strengths of the irons. These values are given in Table II.

TABLE I.—*Percentage Composition and Mechanical Properties of Copper Cast Irons Used for Damping Studies.*

Bar no.	T.C.	Si.	Cu.	Mn.	P.	S.	Tensile strength. Tons per sq. in.	Transverse strength. Lbs.	Deflection. In.	Hardness, Brinell at half radius.
4 ..	3.37	1.00	0.00	0.52	0.22	0.10	18.10	2,850	0.321	205
5 ..	3.36	1.07	1.00	0.52	0.22	0.10	20.30	2,900	0.261	221
6 ..	3.32	1.09	1.72	0.52	0.22	0.10	21.85	2,950	0.243	245
12 ..	3.36	1.09	2.09	0.54	0.22	0.09	21.85	3,850	0.312	259
13 ..	3.39	1.08	3.01	0.54	0.22	0.09	23.00	3,450	0.300	244
30 ..	3.16	1.54	0.00	0.57	0.22	0.11	21.65	3,250	0.379	213
31 ..	3.20	1.50	0.53	0.57	0.22	0.11	21.20	3,350	0.378	218
32 ..	3.18	1.59	0.99	0.58	0.23	0.11	22.30	3,250	0.300	228
33 ..	3.15	1.58	1.45	0.58	0.23	0.11	23.65	3,300	0.300	233
34 ..	3.18	1.49	1.98	0.58	0.23	0.11	24.35	3,600	0.312	242
35 ..	3.16	1.44	3.10	0.58	0.23	0.11	25.00	3,550	0.291	253
47 ..	2.90	1.57	0.00	0.57	0.21	0.10	24.80	3,500	0.347	225
48 ..	2.89	1.57	1.01	0.57	0.21	0.10	26.10	3,500	0.278	246
49 ..	2.87	1.58	1.34	0.57	0.21	0.10	26.80	3,600	0.281	253
50 ..	2.91	1.54	1.95	0.56	0.22	0.10	26.55	3,400	0.252	261
51 ..	2.96	1.56	3.00	0.56	0.22	0.10	26.80	3,750	0.293	266

TABLE II.—*Copper Cast Irons used in the Damping Studies and a Summary of Their Damping Capacities at Stresses Equivalent to 15 and 35 per cent. of the Tensile Strength.*

Bar no.	Cu. Per cent.	Tensile strength 1.2-in. section. Tons per sq. in.	Per cent. damping capacity at stresses equal to 15 per cent. T.S.	Per cent. damping capacity at stresses equal to 35 per cent. T.S.
High-carbon cast irons.				
4 ..	0	18.05	9.9	23.4
5 ..	1.00	20.30	10.5	19.6
6 ..	1.72	21.85	10.6	19.5
12 ..	2.09	21.85	10.1	19.7
13 ..	3.01	23.00	11.0	19.7
Medium-carbon cast irons.				
30 ..	0	21.65	9.0	21.3
31 ..	0.53	21.20	9.8	19.3
32 ..	0.99	22.30	9.7	18.2
33 ..	1.45	23.65	9.8	19.8
34 ..	1.98	24.35	10.0	20.4
35 ..	3.10	25.00	9.2	15.1
Low-carbon cast irons.				
47 ..	0	24.80	7.2	19.0
48 ..	1.01	26.10	7.6	15.2
49 ..	1.34	26.80	7.8	15.1
50 ..	1.95	26.55	7.7	14.3
51 ..	3.00	26.80	7.8	14.6

This information is probably of greater practical importance than is the information on damping capacities given in the charts. It takes into account that iron castings are stressed in service considerably below the tensile strengths of the irons. At working stresses equal to 15 per cent. of the tensile strength, the damping capacities of the irons appear to increase with the alloy content. Somewhere between a working stress of 15 and 35 per cent. of the tensile strength, this order in the damping capacities is reversed, the copper irons then becoming of lower damping capacity than the irons without copper. In engineering applications, cast irons are seldom called upon to resist stresses that are above 20 per cent. of the tensile strength. It appears probable that the damping capacity at working stresses, computed on the basis of a certain percentage of the tensile strength, may be benefited by strengthening with copper.

Endurance of Copper Cast Irons

The endurance limit of a metal is the highest stress which it will bear for an unlimited number of repetitions without fracture. With ferrous materials, in the absence of corrosion, it is found that, if a specimen withstands 5 to 10 million repetitions of a given stress, it will withstand that stress indefinitely.

The test is usually made by beam loading a rotating test-piece of cylindrical section, so that the stress varies from a maximum in tension to a maximum in compression at each revolution. The stress reported is the maximum tensile or compressive stress, that is, half the stress range. Almost all endurance data for grey irons have been obtained by the standard rotating beam test. Such testing is fully described by the American Society for Testing Materials.[9]

Endurance Testing

The standard test is made on specimens carefully freed from notches by polishing, since steels and non-ferrous alloys are very seriously weakened in fatigue by notches, poor fillets, tool marks or any type of stress raiser that produces local stress concentrations. Grey irons differ from other engineering materials in their immunity to the "notch effect." This has been many times demonstrated, especially by Kommers.[10] As the tensile strength of the iron increases, the iron begins to show a slight effect of the notch, the notched bar endurance limit falling a few per cent. below that of the unnotched bar, but the effect is scarcely evident in irons of 18 tons per sq. in. tensile strength. This is brought out by the references cited. These data and others are plotted against tensile strengths as shown in Fig. 5.

Experimental Data on Fatigue Testing of Copper Cast Irons

The results of a series of fatigue tests on six lots of medium-carbon cast irons containing different amounts of copper are shown in Table III. These tests were made with the standard R. R. Moore high-speed fatigue machines, operating at approximately 10,000 r.p.m. The specimens were of the standard type, machined from the 1.2-in. dia. test-bar. The standard specimen is 0.270 in. in the smallest section, and has a contour swept with a 4.993-in. radius. It is $3\frac{7}{16}$ in. long. The endurance limit, as given in Table III, was determined by testing six specimens of each iron at various loads. A typical SN curve is shown in Fig. 6. As shown in the tabulation, an increase in the copper content is accompanied by a slight decrease in the endurance ratio. This is typical of the high-strength alloyed cast irons.

TABLE III.—*Endurance Limit and Endurance Ratios of Cast Iron containing 3.15 per cent. Carbon, 1.50 per cent. Silicon, Alloyed with Copper.*

Bar no.	Cu. Per cent.	Tensile strength. Tons per sq. in. (*A*)	Endurance limit. Lbs. per sq. in. (*B*)	Endurance ratio. $\frac{(B)}{(A)}$
30 ..	0	21.65	23,000	0.47
31 ..	0.53	21.20	19,000	0.40
32 ..	0.99	22.30	22,000	0.44
33 ..	1.45	23.65	24,000	0.45
34 ..	1.98	24.35	24,000	0.44
35 ..	3.10	25.00	23,000	0.41

Thermal and Electrical Properties of Some Copper Alloy Cast Irons

There are frequent inquiries with regard to the effect of copper additions on the thermal conductivity and the electrical properties of grey cast irons. These inquiries are prompted by the anticipation that the addition of copper, with its high conductivity, may have a more decided effect on these properties of cast iron than the addition of other elements of lower conductivities. The available evidence indicates that copper, in the amounts used in the common engineering irons, has little effect on either the thermal or the electrical conductivity. It is believed that in general the effect of changes in the carbon and silicon contents and the microstructure of cast iron overshadows the effects of additions of normal amounts of alloying elements to the engineering irons.

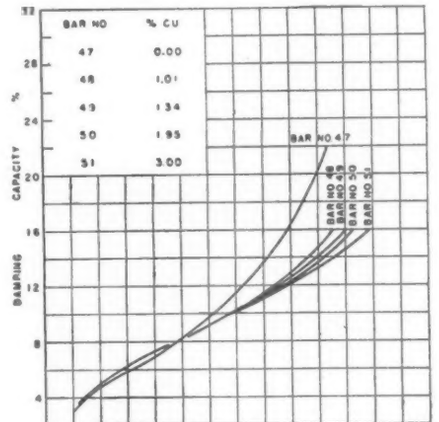

FIG. 4.—DAMPING CAPACITIES OF LOW-CARBON COPPER CAST IRONS.

Thermal Conductivity

The 1940 edition of the "Cast Metals Handbook," page 437, states that the thermal conductivity of grey cast iron varies from 0.110 to 0.137 calories per sq. cm. per sec. per deg. C. These values depend upon the composition and the structure of the iron. As the temperature is increased, the value for thermal conductivity is lowered. Donaldson,[11] in a recent publication, has reported the results of an investigation of the thermal conductivities of high-strength and alloyed cast irons.

To supplement Donaldson's data, the thermal conductivities of a series of medium-carbon cast irons, containing from 0 to 3 per cent. copper, were determined. The method used

was that developed by the National Bureau of Standards. It is described in Research Papers RP 668 and RP 669.[12] The method, in brief, consisted of heating one end of the specimen, measuring the temperature gradient along the specimen and quantity of heat passing through it by means of a heat-flow meter, which is a standard metal of known conductivity in contact with the cold end of the specimen. The specimens were machined from standard 1.2-in. dia. transverse test-bars. They measured 2.0 cm. (0.78 in.) in diameter and 15 cm. (5.85 in.) in length. The results obtained by this method are comparable with those obtained by Donaldson, who used a somewhat different method of measuring the thermal conductivity.

The values for the thermal conductivities at 23, 100, 200, 300 and 400 deg. C., shown in Table IV, were obtained by interpolation of the experimental data. In Fig. 7, the thermal conductivities at 100 deg. C. are plotted against copper content.

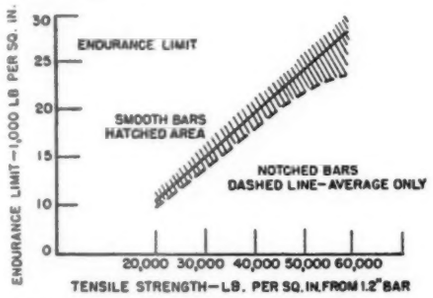
ENDURANCE LIMIT
SMOOTH BARS HATCHED AREA
NOTCHED BARS DASHED LINE—AVERAGE ONLY
ENDURANCE LIMIT—1,000 LB PER SQ. IN.
TENSILE STRENGTH—LB. PER SQ. IN. FROM 1.2" BAR

FIG. 5.—COMPOSITE CURVES OF ENDURANCE DATA ON CAST IRONS, SHOWING RELATION OF ENDURANCE LIMIT TO TENSILE STRENGTH FOR SMOOTH AND NOTCHED SPECIMENS.

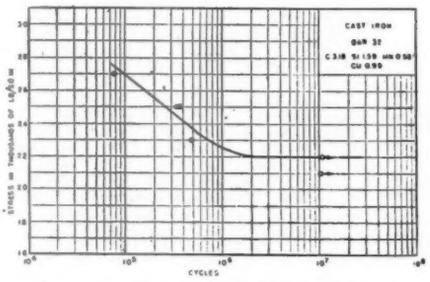

FIG. 6.—TYPICAL SN (STRESS-NUMBER OF CYCLES) CURVE OBTAINED IN DETERMINING THE ENDURANCE LIMIT FOR CAST IRON.

TABLE IV.—*Thermal Conductivity of Copper Cast Irons at Various Temperatures.*

Bar no.	Copper content. Per cent.	Thermal conductivity in cal./cm.²/sec./deg. C. 23 deg. C.	100 deg. C.	200 deg. C.	300 deg. C.	400 deg. C.
30 ..	0	0.112	0.110	0.106	0.103	0.099
31 ..	0.53	0.105	0.103	0.100	0.098	0.095
32 ..	0.99	0.108	0.106	0.103	0.100	0.098
33 ..	1.45	0.108	0.106	0.103	0.099	0.096
34 ..	1.98	0.114	0.110	0.104	0.099	0.093
35 ..	3.10	0.112	0.110	0.105	0.102	0.098

The effect of copper additions on the conductivity was small indeed, although the indication that copper in amounts of 2 to 3 per cent. did not lower the conductivity may be characteristic.

Electrical Resistivity

The electrical resistivities of the same series of medium-carbon irons which were used for the determination of thermal conductivities were measured. This property was determined on bars 0.75 in. in dia. and 21 in. long machined from the 1.2-in. transverse bars. The potentiometric method of measuring the resistance was used. The resistance was measured over a length of 40 cm. (15.7 in.) at a temperature of 23.5 deg C.

The experimental data are summarised in Table V. These results are plotted against copper contents in Fig. 8. The resistivity of the iron increased slightly with the copper content up to 1 per cent. and then decreased with further increases of copper. The resistivity of the copper iron, which contained 2.5 per cent. copper, equalled that of the copper-free iron. From a practical viewpoint, these results indicate that the effect of copper in amounts up to 3 per cent. on the resistivity of cast irons is insignificant.

TABLE V.—*Electrical Resistivity of Copper Cast Irons at 23.5 deg. C.*

Bar no.	Copper content. Per cent.	Resistivity. Ohm/cm. × 10^6.
30	0	58.4
31	0.53	61.4
32	0.99	61.8
33	1.45	61.0
34	1.98	59.2
35*	3.10	57.4

* Specimen 35 was flawed at one end. To avoid the flaw the potential terminals were placed to cover good metal only.

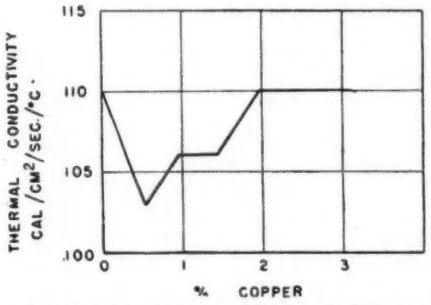

FIG. 7.—EFFECT OF COPPER ON THERMAL CONDUCTIVITY OF A 3.15 PER CENT. C, 1.50 PER CENT. Si CAST IRON AT 100 DEG. C.

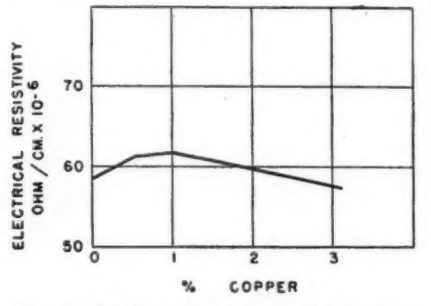

FIG. 8.—EFFECT OF COPPER ON ELECTRICAL RESISTIVITY OF A 3.15 PER CENT. C, 1.50 PER CENT. Si CAST IRON.

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[10] Kommers, J. B., "Static and Fatigue Properties of Some Cast Irons," Proc. A.S.T.M., vol. 28, pt. 2, p. 174 (1928); "Fatigue Properties of Cast Iron," vol. 29, pt. 2, p. 100 (1929); "Effect of Under-Stressing on Cast Iron and Open-Hearth Iron," vol. 30, pt. 2, p. 368 (1930).
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(*Continued in next column.*)

Methods of Analysis of Coal and Coke

Fuel Survey Paper* No. 44, recently issued in connection with the Physical and Chemical Survey of the National Coal Resources, supersedes Survey Paper No. 7, "Methods of Analysis of Coal," which was published in 1927. It embodies the results of continued investigation into the details of the earlier methods, together with certain additional methods for the analysis of coal, and—for the first time in the series of Papers—methods for the examination of coke. The development and improvement of these methods have been achieved by close collaboration between the laboratories of the Department's Fuel Research organisation—*viz.*, the Fuel Research Station and its associated Coal Survey Laboratories. Indeed, the methods now put forward were evolved primarily for use in these laboratories, where a high degree of accuracy is required; they have been published so as to be available to others requiring this high standard, as well as to provide a record of a part of the Department's researches.

The new Paper gives considerably more details of technique and apparatus than the old, and contains suggestions for overcoming certain difficulties. The principal changes in the existing methods relate to those for the determination of volatile matter, nitrogen, phosphorus and agglutinating value. Those included for the first time are for the determination of chlorine, arsenic and the forms of sulphur; additional methods are given for the determination of carbon dioxide and sulphur, and the section on the Gray-King carbonisation assay, previously dealing only with the low-temperature form, now includes a description of the apparatus and method for the high-temperature modification.

The appendices include one on the reproducibility of results, showing the degree of divergence to be expected between determinations made in the same laboratory or in different laboratories. Another deals with the methods of reporting results, and particularly the method of calculating them to the mineral-matter-free basis, or pure coal substance.

* Fuel Survey Paper No. 44—"Methods of Analysis of Coal and Coke." H.M. Stationery Office, price 2s. net.

Static Electricity on Belts

A well-known chemical company recently conducted tests with a General Electric electrostatic voltmeter to find out the extent of the static electricity generated on conveyor belts, motor drive belts, rubber-tyred trucks, and from actual walking on floors. In the case of the V-belt of a 25-h.p. motor, observation of the discharge spark indicated the presence of approximately 37,000 volts. Another test showed that 6,000 volts were generated simply by walking across the carpet of an office. As a result of more extensive investigations, belt dressings were examined to find one of a conducting nature that would permit a continuous discharge of accumulated static electricity, while trucks were equipped with grounding chains, and various types of flooring were also investigated. The voltmeter used in the tests was a 20,000-volt portable instrument designed for both a.c. and d.c. measurements of voltage on systems where one line is grounded, operation simply calling for grounding of the case, energising the light source, and making the high-voltage connection.

(*Continued from previous column.*)

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Shelton, S. M., "Thermal Conductivity of Some Irons and Steels over the Temperature Range 100 to 500 deg. C.," Bureau of Standards Journal of Research, vol. 12, pp. 441-450 (1934).
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Increasing the Open Fire's Efficiency

THE HALES CONVECTOR

Research on the problem of increasing the efficiency of the open fire has been going on for some considerable time under the direction of the Senior Research Officer of the British Coal Utilisation Research Association, Mr. J. S. Hales. As a result, the Hales convector has been developed.

The Hales convector is a double-duty fire, the basic principles of its heating being convection plus radiation. The convector makes use of the heat which is normally lost in the firebrick and the walls. It can be installed without any structural alterations, and it is designed to fit most fireplaces 16 in. or 18 in. wide and of minimum height of 22 in. The convector, which is a complete cast-iron grate with its own stool bottom and fret, is placed inside the existing grate, and is sealed off at the bottom and at the top. A hollow space is left between the cast-iron back and sides of the convector and the existing firebrick. When the fire is lit and the iron gets hot the air in the hollow space warms up and emerges through the louvres at the top of the convector's frame, and is replaced by cool air which enters through the slots at the bottom. In this way a constant supply of warmed air is circulated through the room, supplementing the radiated heat from the burning coal. The sealing at the top and bottom of the convector's casting ensures that all the products of combustion go up the chimney as usual.

Fuel Saving Achieved

Tests made by the British Coal Utilisation Research Association, in which the Hales convector was compared with an ordinary grate under identical conditions, have shown a saving of 40 per cent. of coal for an equivalent heat output. In a room fitted with a good modern grate, burning 2.65 lbs. of coal per hour on an average winter day, the consumption would be reduced to 1.6 lb. per hour if the Hales convector were fitted. In addition to this the temperature in the room would be slightly increased. Trial units have been installed in a number of private houses, and householders have amply—and enthusiastically—confirmed these facts. In several cases savings up to 50 per cent. have been attained.

A leading industrial designer has been called in and has produced a really modernistic front. Obtainable in a number of attractive finishes, it will successfully harmonise with every form of decoration.

The introduction of the Hales convector is being sponsored by the Coal Utilisation Joint Council and C.U.R.A. Patents, Limited. It will be possible, however, to manufacture only a limited number of convectors for the coming heating season for sale mainly in the Greater London area. It is hoped that householders, building estates and merchants installing the device this winter will collaborate with the C.U.J.C. and the B.C.U.R.A. by keeping records of the coal consumed and the savings effected as compared with the normal open fire, thus providing practical data in support of the scientific tests already carried out.

Institute Awards

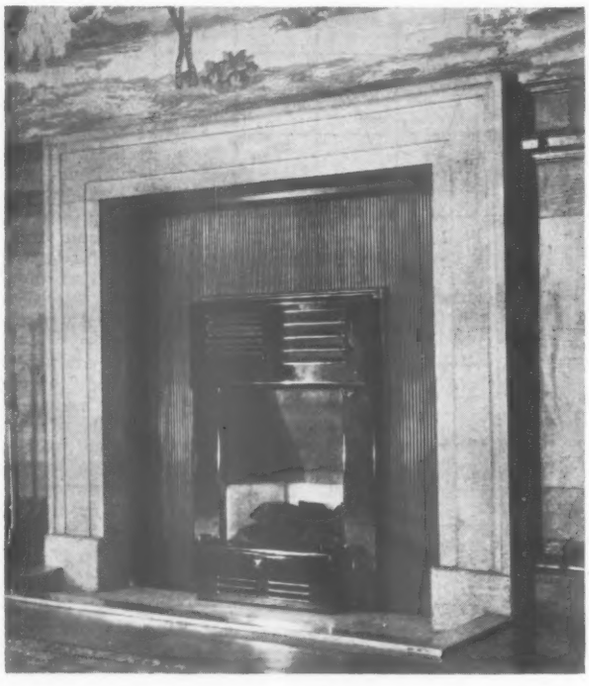
At a meeting of the Council of the Institute of British Foundrymen, held in Birmingham recently, the following awards were made:—

Oliver Stubbs Gold Medal

Mr. A. E. Peace, chief chemist of Ley's Malleable Castings Company, Limited, was awarded the Oliver Stubbs Gold Medal in recognition of the contributions he has made to the metallurgy of cast iron through the many Papers he has read before the Institute, coupled with the valuable services he has rendered to the industry through his work as convener of the Malleable Cast Iron Sub-Committee of the Technical Committee of the Institute.

Meritorious Service Medal

On the recommendation of the Executive Committee, this medal has been awarded to Mr. John Bell, the honorary secretary of the Scottish Branch of the Institute, in recognition of the outstanding manner he has carried out his duties for the seventeen years during which he has held office.



THE HALES CONVECTOR.

Diplomas

The following were awarded the diploma of the Institute for Papers which have been presented to the Institute:—

Mr. E. W. Dowson (joint author with Mr. C. H. Kain), for a Paper on "The Design of Test-Pieces for Carbon Steel Castings."

Mr. J. L. Francis, for "The Production of Pressure-Resisting and High-Duty Iron Castings."

Mr. H. G. Hall, for "Malleable Cast Iron."

Mr. A. Hopwood, for "Phosphor-Bronze Castings of Heavy Section."

Mr. J. Laing, for "Gating and Pouring Temperatures in Non-Ferrous Foundry Practice."

Mr. A. Marshall, for "Production of Some Engineering Castings."

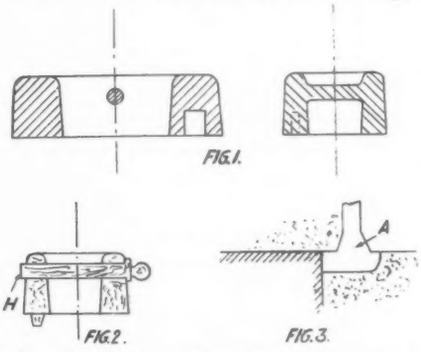
Mr. A. J. Shore, for "Principles of Foundry Management."

Mr. R. C. Tucker, M.A., for "Chromium Heat-Resisting Cast Irons."

Some Jobbing Foundry Experiences—XI

By "TRAMP"

Fig. 1 is a sketch of a common type of a 56-lb. weight as is occasionally required from jobbing foundries. To those unaccustomed to this class of job it may be thought that a core is necessary to make the interior. This is not the case if the pattern is made correctly, for not only would a core entail more labour and drying costs, but it also would prove rather difficult to match up correctly, as a dry-sand core and a green-sand mould seldom produce castings without an unsightly fin at the junction of the mould and core. Fig. 2 shows the pattern, which is practically a replica of the casting, excepting that the handle H is made as a loose piece and kept in position by holes through the side. The recess in the back (provided to hold any lead necessary to bring the casting up to weight after continuous use) is cored out, a print being dowelled on the back for this purpose. The method of manufacture adopted is as follows:—After placing the pattern on a true board, the interior is rammed and sand also tucked around the outside up to



the handle, which is then drawn out. A suitable moulding box is placed around the pattern and a piece of slate placed close against the pattern, thus covering the hole through which the piece forming the handle has been withdrawn. Ramming is continued and the bottom turned over, the top rammed and lifted, and the pattern withdrawn. The runner being cut and a riser placed over the heavy portion, the core is wired in the top and the job assembled ready for casting. In many shops weights and similar lumpy castings are produced by either "pencil" or "block" runners, but the success of this method depends on very hot fluid iron. In some small jobbing shops this iron is rather difficult to obtain, and other means are adopted to ensure soundness. The riser is made of ample size and rod-fed, while the runner is on the large side and the downgate placed near the pattern and swelled out to form a reservoir from which the shrinking casting may obtain a supply of fluid iron, as at A, Fig. 3.

Heat Etching for Studying Grain Size

Austenite grain size may be revealed by heat-etching using the procedure described by M. J. DAY and J. B. AUSTIN in the "Transactions of the American Society of Metals." The polished specimen is heated in a vertical furnace in purified hydrogen, nitrogen or cracked ammonia, and quenched in mercury. There is no marked loss of carbon in eutectoid steel after 24 hrs. at 1,095 deg. in hydrogen. The grain boundaries are revealed as deeply etched lines, and "ghost" networks may be obliterated by a wrinkled skin, probably consisting of martensite formed in quenching. Boundaries detected agree with those shown by the gradient quench and grain-size etching methods. The technique described is especially useful for studying the rate of grain growth at various temperatures, and may be used with pure iron and low-carbon steels, as well as with high-alloy steels.

Vibration in Electrical Machinery

DIAGNOSING THE TROUBLE

Vibration in electrical machinery is an objectionable feature and capable of undesirable results. The causes, moreover, frequently are very difficult to trace. The subject is discussed in an interesting article by MR. D. B. HOSEASON in "The Metropolitan-Vickers Gazette," the author first dealing with methods for balancing moving parts and then reviewing some of the factors which give rise to vibration.

To the electrical machine engineer, vibration is unwanted movement, usually of a high frequency. If a body is very rigid, even though there may be an appreciable periodic disturbing force, there will be no apparent movement and no vibration. For vibration to take place, there must be a periodic disturbing force and a response of the affected part. It may occur because the disturbing force is large and the responding part of insufficient strength, or, on the other hand, the disturbing force may be small and its frequency correspond with the natural frequency of the affected part. When considering methods of rectifying trouble, it is important to differentiate between these two sources of vibration. It should also be noted that the designer of an electrical motor is always liable to have a disturbing force impressed on his machine from the driven apparatus—perhaps of only small amplitude, but which nevertheless happens to coincide in frequency with some part of his machine.

Radial and Axial Bumping

A form of inherent vibration which occurs from time to time on machines when running light, on motor-generator sets or direct coupled motors with flexible couplings, is "radial bumping." This may occur with either sleeve or ball and roller bearings, although in the former case there are two quite different possible causes of the trouble. On some high-speed sleeve bearing machines, particularly where there is a large radial clearance between the journals and the bearings, the lapping in of the oil by the rotation of the shaft lifts the latter, and thus the entire rotor, usually raising the journal to a position above the centre of the bearing shell and a little to one side. The upward movement tends to reduce the oil pressure in the lower half of the bearing, and with suitable conditions instability may occur allowing the rotor to sink again. This rise and fall of the journal in the bearing is periodic, and if the weight of the rotor is within certain limits, resonance may set in and the vibrations become violent. The remedy is usually to reduce the clearance in the bearing and, if possible, to modify the positions of the oil grooves.

The second possible cause of radial bumping occurs in either sleeve or ball and roller bearings. When an electrical machine is first erected, it is customary to make the air gap somewhat larger at the bottom than the top, so that any settling of joints or parts in service will bring the rotor nearer central. With bearings this also allows for some wear of the bearing linings. This offsetting produces an unbalanced magnetic pull in a vertical direction which opposes the normal gravity effect due to the weight of the rotor. Occasionally, these two forces so nearly balance that the slightest inequalities in dynamic balance or in bearing construction lead to erratic behaviour of the journal in the bearing or of the inner race in the rollers and cause vibration. The phenomena are rarely severe and the movement is often not truly periodic. Nevertheless, noise is produced in the bearings, often suggestive that serious trouble is developing, although no case of failure from this cause is known. The remedy is to readjust the air gap so that a definite uniform load towards the lower half of the bearing exists.

In sleeve bearing machines vibration of a serious nature may be established by "axial bumping." This usually takes place on drives with a fluctuating torque, such as compressors and ram pumps. If the equipment is erected so that the rotor or armature is slightly displaced axially with respect to the stator or field, the fluctuating load current gives a periodic impulse in an axial direction. With end play and a suitable weight of rotor, resonance sets in, and cases are known in which the thrust faces on sleeve bearings have completely collapsed under the violent periodic blows. The remedy is to adjust the set-up to bring the rotor axially central with the field.

Shaft-Transmitted Vibration

Trouble from vibration transmitted from the driven machinery along a motor shaft, or from an engine to a generator, is not common. When it does occur, however, the consequences can be very serious and the tracing of the trouble difficult, as it is not easy to measure torsional oscillations or vibration on a rotating shaft.

Diesel-driven generating sets, ram pumps, and reciprocating compressors are the types of drive on which it is desirable to watch for trouble. Laminated cores must be tight on their spiders, and the latter a correspondingly tight fit on the shaft. Experience has proved many times that if the press fits of these parts are not adequate, no combination of keys and keyways will stand up to the cyclic irregularity. Chain drives between the driving and driven machinery have been known to resonate with the disturbance, with the consequence that the bearings of the electrical machine have collapsed under the violent surging of the chain.

A further type of vibration transmitted to a motor *via* its shaft is that which arises from overhung pinions or badly-fitted couplings on drives which are very rough running, such as colliery haulages. In a particular case, the frequency of the vibration happened to coincide with the natural frequency of the fan blades of a rotor. The method of overcoming this was to fit a modified design of fan in which the fan blades had their stiffness, natural frequency and damping increased considerably by a modified form of construction. It is preferable, of course, to prevent the vibrations reaching the motor if possible, but in the case recorded the drive was through an overhung pinion. Shaft-transmitted vibration is also very liable to lead to trouble on the brushgear of slipring motors, and, apart from sparking and burning of the sliprings, the actual brushes are sometimes so hammered and distorted that they become wedged in their brush holders.

The preferable method of treatment for this type of trouble is to remove the disturbance at its source or to prevent the vibration actually reaching the motor. A truly flexible coupling would be effective, but experience shows that a great many so-called flexible couplings on the market will not prevent the transmission of vibration. Furthermore, some designs of coupling which do prevent the vibration reaching the motor, break down under the alternating stresses.

Foundation-Transmitted Vibration

Trouble from vibration transmitted through foundations is, in general, limited to two principal types of drive. First, there are coal pulverisers, ore crushers and plant in which the driven machinery generates very severe vibration in its normal operation, even though mounted on robust foundations. The other class of drive which may give trouble is the semi-portable installation, such as a marshalling haulage near the coal face in a mine where the plant is mounted on light girders and where the quality and alignment of the gearing is often very poor. With a well-designed flexible coupling, it should be possible to reduce to a minimum vibration transmitted along the shaft in these cases, but there will still be a considerable amount transmitted to the driving motor through the girders and foundations.

The general method of dealing with foundation-transmitted vibration is to isolate the base of the motor from the driven machine. This, however, is not always possible and the user has often to fall back on the motor manufacturer to produce a design which will withstand the service. Brush holders constructed from extruded brass parts riveted together do not stand up well to vibration, and cast brass is to be preferred. Graphitic brushes, being lighter than the copper graphite type, follow the movement of the sliprings more readily, and consequently reduce sparking. At least two brushes per slipring set at 90 deg. are desirable, so that one brush out of the set maintains electrical contact with the ring. Large high-speed ball mills may operate reasonably smoothly when first installed, but after some time the balls develop flats, become out of round, and the vibration of the mill becomes very severe.

Roller-Track Indentation

A type of trouble which may occur on ball and roller-bearing machines when the rotor is not revolving is "track indentation." Since this develops with the rotor stationary, it is generally due to foundation-transmitted vibration, although many cases are on record of the damage being done during shipment to site. This may result from the use of hard-tyred lorries, badly sprung railway trucks, or location in a ship's hold where severe vibration exists. Standby motors in Diesel-driven ships are very susceptible. Several cases are also on record of duplicate pumping sets side by side on the same foundations suffering from this complaint, where one pumping set is standby to the other. The standby pump is subjected to vibration from the running plant and allowed to remain stationary too long. In some cases, the cure has been merely to run the sets on alternate days instead of alternate weeks. If it is known beforehand that severe foundation-vibration is likely to take place while a motor is stationary, it is desirable to use sleeve bearings. This applies particularly for auxiliaries standing near Diesel engines. If the motor is running fairly continuously, ball or roller bearings are, of course, quite satisfactory.

It must be remembered with all vibration troubles that the designer of the electrical machine cannot possibly undertake to produce a construction which will always be immune from even normal vibration in service. If the impulses from the driven machine happen to strike the natural frequency of some part of the electrical equipment, such as a brush spring or a fan blade, it will undoubtedly collapse, even though the disturbing force is small. The designer must, therefore, be prepared for isolated instances of this type, and be ready to change his design slightly so as to alter its natural frequency. The purchaser in turn must expect these cases and not necessarily insist on major alterations when they are not fundamentally required.

D

Production of Pig-Iron in the Electric Furnace*

By CHARLES HART

The art of electric smelting came with the turn of the present century, and owes its existence to the introduction of alternating current, which found its first wide use in the establishment of the great power plants at Niagara Falls, N.Y. Prior to that time current was largely direct. The furnaces were electrolytic in nature and found their first metallurgical use in the production of aluminium, and this process still prevails.

The normal production of pig-iron up to that time was carried on in blast furnaces in which charcoal, coke and anthracite were used as the fuel. This new electric process called for sufficient carbonaceous material to reduce the oxides and impregnate the pig-iron with sufficient carbon, but the remainder of the energy was to be supplied by electric power. The chemical reactions are essentially the same in electric smelting as obtains in the older blast furnace. All of these data are so well known in both methods as to need no discussion at this time, for they can be found in scientific publications and books written during the first two decades of this century.

operation: (1) the "Elektrometalls" or high-shaft furnace of Sweden, and (2) the low-shaft or pit-type furnace as offered by Tysland-Hole and Siemens-Halske.

The "Elektrometalls" furnace takes its name from the corporation formed by the engineers who had undertaken its perfection. After trying several designs they brought forward the furnace shown in Fig. 1, which by the way is the highest development of this type of furnace to-day.[1] Note the trend in the lines, which have kept pace with modern blast-furnace design. The high-shaft furnace lends itself to skip filling and is fitted with tuyeres immediately under the crucible roof, whereby the gases are recycled and the roof preserved.

The failure of the Elektrometalls furnace in Norway, because of its inability to meet silicon requirements and to use coke as the fuel, led to trials of the pit-type furnace, which is shown in an intermediate stage in Fig. 2, and which found its greatest perfection in the furnace designed by Hole[2] (Fig. 3). This type of furnace is now being installed in the greatest number throughout the world. It is lateral-filled, with electrodes are essentially continuous. The Söderberg electrode[3] as designed consists of sheet-iron tubes welded in place and filled with electrode material as required, and in effect are continuous. The Elektrometalls furnace (Fig. 1) is equipped with eight Söderberg electrodes of 28-in. dia. The "Spigerverks" furnace (Fig. 3) has three electrodes of the same type 43 in. in diameter. This furnace and these electrodes are controlled by the Norske Aktieselskab for Elektrokemisk Industri.[3]

The Elektrometalls furnaces (Fig. 1), five in number, have an electric power intake of 6,300 kw. each, and produce a pig-iron suitable for the Thomas Gilchrist steel process, using a high-phosphorus sintered magnetite. This improved furnace uses two-thirds charcoal and one-third high-ash coke and coke breeze.[1] Elektrometalls electrode consumption is about 20 lbs. per ton of pig-iron produced, with a power consumption of 2,500 kw.-hrs.[3]

The high-shaft furnace, although eminently successful in Sweden, failed to meet the requirements in Norway because of the lessened electrical resistance of coke when heated as compared with charcoal, and on this account failed to produce high-silicon foundry iron.

At Tinfos,[2] during the years 1910 to 1922, a furnace bearing that name produced pig-iron with only moderate success. This furnace was of the direct-heating arc type with three suspended electrodes. It was an open-top low-shaft furnace. Tysland[2] brought forward the Tysland furnace in 1922, after experimentation

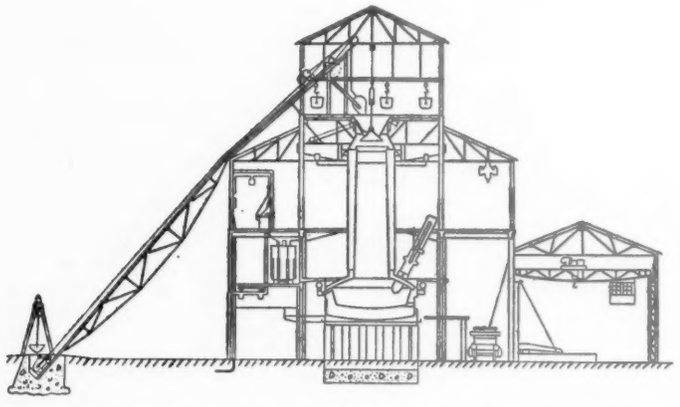


FIG. 1.—SWEDISH SHAFT FURNACE, DOMNARFVET IRON AND STEEL WORKS, DOMNARFVET, SWEDEN.[1]

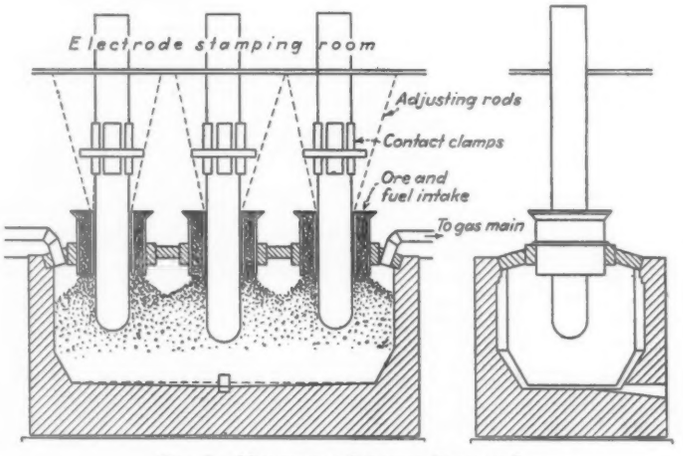


FIG. 2.—NORWEGIAN PIT-TYPE FURNACE.[1]

Types of Furnaces

The 40 years devoted to the practice of electric smelting may be divided into two periods of 20 years each. The first was devoted to experimentation with furnace types and with many publications on theories and processes. The second half of this term was devoted to perfecting the types of furnaces and their active commercial operation.

The arc furnace may be found in three types: (1) the direct-heating arc furnace with the positive electrode included in the bottom and the other electrode suspended above; (2) the independent arc furnace with its electrodes entirely above the charge, which of necessity depends upon heat reflected from the roof, and (3) the direct-heating series arc furnace equipped with two or more electrodes suspended from the roof.

Of these three types, only the last is used in electric smelting of iron ore at the present time. The elimination of the other types automatically removed many of the early designs, to the end that there are now only two general types in

* Extracts from a Paper read before the American Institute of Mining and Metallurgical Engineers. The author is President of the Delaware River Steel Company, Chester, Pa.

electrodes at the angles of an equilateral triangle. The Siemens-Halske[3] type (Fig. 4) is essentially the same as to electrode arrangement, but is centre-filled, which permits mechanical charging.

Stassano, as early as 1898, designed a smelting furnace of the independent arc type, by placing horizontal electrodes at the tuyere positions in a small furnace with lines identical with the blast furnace of that day. Its faults are apparent. Moissan tried the same principle, and also failed. Dr. P. L. T. Héroult was irrevocably committed to the direct-heating arc type. He and his disciples failed completely, and both types have disappeared from commercial operation.

The inadequacy of the available electrodes became apparent in the early efforts at electric smelting. The early experiments with the Elektrometalls furnace required electrodes with a cross-sectional area of 242 sq. in., three in number, made up of smaller ones bound together, which were so short that butt-end loss was excessive and amounted to as much as 40 per cent. in extreme cases. The prefabricated electrode[4] as now produced has met all requirements, in that practically any diameter within reason is available. Excessive loss is avoided by joining the ends by screw threads, and these which resulted in a direct-heating series arc type, still with an open top. It was tried out at the Christiania Spigerverks (Oslo Nail Works) in 1925.[3] Ivar Hole[5] took over in 1928 and improved upon the Tysland design by building an airtight non-explosive furnace, essentially the same as shown in Fig. 4 except that it was equipped with gas-exhausting machinery.[1] Söderberg electrodes are used as indicated by the stamping room as shown.[1] The latest arrangement[6] (Fig. 3) is trefoil in character, with electrodes placed at the angles of an equilateral triangle. Lateral charging is maintained and its advantages may be seen in the absence of erosion at the charging hoppers, as compared with that shown adjacent to each electrode—an erosion fittingly attributed to turbulence.[11]

The Radex brick shown are made in Austria, either of magnesite or of chrome and magnesite mixed. Bricks of equal quality to this high-temperature brick are produced by the American refractory companies. The Chamotte brick are a first-grade fireclay brick.

The location of the charging doors has a beneficial effect on electrode consumption, which is placed at 17 to 22 lbs. per ton.[3] Owing

to the use of coke, this compares most favourably with the Elektrometalls practice on charcoal. The electrodes can be increased in number and as much as 175 volts may be used.[3] It is possible, therefore, greatly to increase the daily production of 100 tons now possible from a 12,000-k.v.a. furnace. Practically all carbonaceous materials serve as fuel, but a preference for coke and coke breeze is indicated.[4]

Efficiency of Furnaces

In Table I relative results obtained on the two furnaces just described are shown.[7]

TABLE I.—*Comparison of Two Furnaces.*

	Elektro-metalls.	Spiger-verks.
Charcoal per gross ton, lbs. ..	810	887
Electric energy per ton, kw.-hr.	2,040	2,166
Yield of ore, per cent.	56·8	57
Agglomerates in mix, per cent.	89·1	85·5
Iron analyses, per cent.: Si ..	0·50	0·62
Mn	1·00	0·61
Average electric load, kw. ..	3,775	5,067
Average daily production, tons	44	56

The Spigerverks furnace had a rating of 9,600 kw., but the highest reached was 7,500 kw.

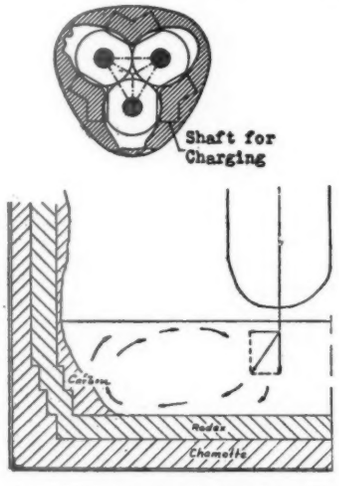


FIG. 3.—SMELTING ZONES, SPIGERVERKS FURNACE AT IMATRA WORKS, FINLAND.[6]

(From H. Willners, Supplement to Reference 2.)

It is evident that situation would have been helped materially had this furnace worked on coke, for which it is particularly designed. Therefore, all comparisons are unfair to the Norwegian furnace. The real test for these furnaces is in their commercial results. In Table I, the Elektrometalls furnace shows a material advantage over the Spigerverks in consumption of charcoal and current, and by these standards a ratio of 11 to 10 in favour of the Swedish plant is indicated. But in reality, by calculating the costs of the materials used, the commercial ratio changes to 5 to 4 in favour of the Tysland-Hole design.

A better gauge of the efficiencies of the smelting furnaces is reflected in the analyses of the escaping gases. Table II gives a comparison of the gases from the Elektrometalls and Spigerverks furnaces. These furnaces worked under the most favourable conditions. The analysis of the gas from a normal blast furnace equipped with a Gayley dry blast, as reported by the late A. E. Macoun,[8] is also shown.

The CO_2:CO ratio in Table II is the true index of the relative efficiency of the two electric furnaces, while the Macoun column, with reference to columns 1 and 2, indicates the relative value of the electric furnaces when compared with the blast furnace. In the former case only sufficient carbon is added to the charge completely to reduce the oxides pertinent to the operation, while in the latter the heat for fusion and other purposes is furnished by the combustion of the coke. The gases in each case respond to results obtained from the Mathesius formula,[9] in that the Elektrometalls analysis indicates some reduction above the tuyeres. The Spigerverks furnace, with neither tuyeres nor stack, indicates maximum reduction in the hearth. The Macoun results show economy due to indirect reduction in the stack. The normal blast furnace burns seven-eighths of the charged carbon completely to CO_2, which is immediately converted into CO by the ever-present incandescent coke, and at a point practically 50 ft. below the stock line the CO_2 from the flux enters the gas stream. The various reactions as between the materials in the furnace result in a gas of the analysis shown in the third column of the table. A contributing factor to the efficiency of these three furnaces is the possibility of using the gases in auxiliary operations. Data covering this feature are shown in the table. It is impossible to convert the Spigerverks gas into electricity in competition with hydroelectric current, unless the cost of such power exceeds 2.33 mills per kilowatt-hour, because the current made from this gas in a modern reciprocating gas-engine plant

TABLE II.—*Comparison of Gases.*

Gases.	Elektro-metalls.[2]	Spiger-verks.[2]	Mac-oun.[3]
Carbon dioxide, per cent...	23·00	15·00	16·23
Carbon monoxide, per cent.	62·00	78·00	22·75
Hydrogen, per cent. ..	1·50	1·00	0·02
Methane, per cent... ..	1·50	1·00	1·39
Nitrogen, per cent. ..	1·50	1·00	58·86
Ratio CO_2 to CO	1 : 2·69	1 : 5·20	1 : 1·40
Gas per ton, cub. ft. ..	18,259	22,600	132,524
Heat value per cub. ft., B.Th.U.	279	292	80
Temperature of escaping gas, deg. F.	392	480	324

would cost the same amount, and would be made up of 0.088 mills for operating costs with the balance chargeable to interest and depreciation. Its value as a fuel for other operations, figured at 0.9 mill per kw.-hr., equals approximately 4s. per ton on the pig-iron produced.

The Elektrometalls furnace gas shown has a lower energy value, but the reduction within the furnace was more effective owing to the recycling of the gas. Were it not for this feature, the carbon dioxide content would be 10 per cent. or less and the gases would be proportionately more valuable for use as fuel.

The great volume of gas coming from the blast furnaces, as shown in Table II, results from the nitrogen content in the air. The blast furnace is cited as being the most efficient of all the processes used in iron and steel metallurgy. The maximum heat value obtainable from the case quoted[9] is 22,000,000 B.Th.U., while the calorific value of the escaping gas is nearly 11,000,000 B.Th.U., of which roughly 20 per cent. is available for purposes other than in the furnace operation. This, however, is increased to 70 per cent. when applied to furnaces equipped with reciprocating gas engines. It would seem, therefore, that the demands upon energy are based upon the work to be done. This work varies with the types of ores used, the value of the fuels, and the quality of the pig-iron desired—and there is no short cut available. Rich gases indicate poor reductive reactions in the furnace.

The carbon dioxide content in the electric furnace is of such moment that burned lime is preferable as a flux, rather than the natural stone. However, in the Swedish practice a preponderance of fines is undesirable. In Norway it has been found worth while to use calcium ferrite, made by the Rolfsen process, as a flux.[3] This practice has the added feature of reducing the slag volume.

Sweden was the leader in electric smelting, and the furnaces as designed met conditions as they existed at the time the art was introduced. Norway was forced to meet existing conditions and, as already stated, turned to the pit-type furnace.

Advantages of Spigerverks Furnace

For general use and for world-wide conditions, the Spigerverks furnace has the following advantages:—(1) Lateral filling, which increases the life of the furnace; (2) higher voltages, which make possible increased production; (3) higher temperatures, which permit better sulphur removal; (4) use of low-grade fuels, which materially reduces costs; (5) closed type in design, absolutely explosion proof; (6) the furnace acts as a "metal mixer" as well as an "electric accumulator." These advantages give the Spigerverks furnace the call in practically all new installations, which have included two recently erected in Sweden. In spite of the great improvement manifest in these two types of electric furnaces, world production of electric

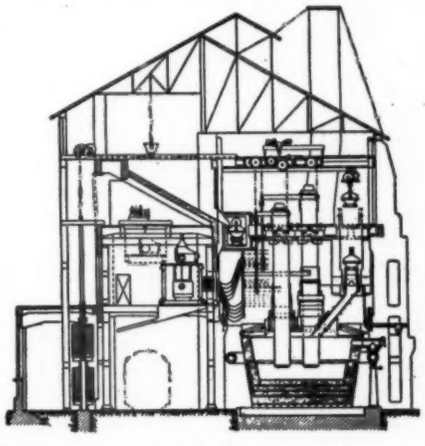


FIG. 4.—ELECTRIC LOW-SHAFT FURNACE BUILT BY SIEMENS-HALSKE[6]

pig-iron is relatively small and is confined entirely to European countries. The average annual output for the years 1935 and 1936 was 205,517 gross tons, or less than 0.25 per cent. of the world total for the same period.

Sweden

In the period 1935 and 1936, Sweden produced an average of 57,242 gross tons of electric pig-iron, which was 9.3 per cent. of that country's total output. This figure indicates a decided decline from peak operations in the year 1924, when a total of 90,000 tons was made, or 19.4 per cent. of that year's output of pig-iron. The results of operations for the year 1937 are also indicative of the trend in iron smelting in Sweden. In that year 58,810 tons[10] of electric pig-iron was produced, or 36.4 tons average per day for six furnaces using current in connection with charcoal. The electric current consumption was approximately 2,400 kw.-hrs. per ton of product. These furnaces operated at an average of 243 days for the year, as compared with an average of 281 days for the 39 charcoal furnaces, which produced an average of 28.6 tons per day. The output of non-electric iron was about evenly divided as between coke and charcoal iron, made in ordinary blast furnaces.[10] The coke furnaces produced a daily average make of 130 tons.[10]

The rate for electric power in Sweden[1] was 3.5 mills per kw.-hr. at the customers' transformers, subject to a rebate of 10 per cent. to

the electric smelters. In addition to this rebate, seasonal power was furnished at reduced rates, depending upon the number of months the furnaces operated during the year. These rates ranged from 0.63 mill for one month to 3.15 mills for the entire year. This schedule of rates would indicate that for 1937 the average rate paid on the 2,400 kw.-hrs. consumed per ton of iron was 1.89 mills. In that year charcoal sold at about £2 10s. per net ton. Sweden's charcoal consumption in blast-furnace practice is placed at 1,350 lbs. per ton of iron, which indicates a fuel cost of £1 14s. per ton. Table I shows a possible fuel cost of £2 15s. per ton on electric pig-iron, assuming continuous operation throughout the year. The figures are based upon the use of agglomerated ores in the charcoal furnaces as well as in the electric furnaces.

The total annual capacity of electric smelting furnaces in Sweden may be placed at 100,000 tons. Sweden is credited with a total potential waterpower capable of producing 32,500,000,000 kw.-hrs. per year. Only 5,500,000,000 kw.-hrs. are now available, which represents only one-sixth of the possible total electric energy. Viewed in this light and in conjunction with the increased costs for charcoal due to diversion of timber products to more remunerative markets, it would seem that the electric smelting of iron ores has not been the bonanza prophesied for it at the time of the introduction of the art. Sweden, however, should be credited with being the initiator of this unique method of iron metallurgy.

Norway

Norway,[10] for the same period, 1935 and 1936, had an average annual output of 33,497 tons of pig-iron. Of this tonnage, 32,068 tons, or 92.7 per cent., was produced by the electric method with the use of low-priced and inferior coke and coke breeze. This fact emphasises the adequacy of the pit-type furnace for Norway's requirements.

The cost of power is said to be about 1 to 1.5 mills per kw.-hr. This cost of power has attracted ferro-alloy manufactures, to the end that 145,000 tons of these products was produced in the year 1937. In the same year 32,000 tons of electric pig-iron was produced. The operation consumed an average of 2,550 kw.-hrs. and 893 lbs. of coke and coke breeze per ton of product.[10] In addition, 4,000 tons of iron was produced as a by-product in an aluminium plant operated by the Pederson process.

France

Only meagre information is obtainable as to the types of electric furnaces used in France for the production of pig-iron. It is intimated that much of this iron is synthetic in nature, and the industry depends largely on scrap and ore as the materials to be smelted. For 1935 and 1936, the average annual output is placed at 53,645 tons, or 0.9 per cent. of the country's entire production for the period. The power cost is placed at 2 mills per kw.-hr.

Italy

An interest in electric smelting in Italy may be attributed to the fact that there is a woeful lack of good coking coal, as well as that 30 per cent. of the iron-bearing materials as offered to the smelters consists of agglomerated pyritic residues. The pit-type furnace is highly appreciated because of the high temperatures obtainable, whereby it is easy to reduce the 0.50 per cent. sulphur found in this material to 0.03 per cent. in the pig-iron. These facts account for the production of 62,567 tons of electric pig-iron, from this material, in low-shaft furnaces. Italy produced a greater tonnage of electric pig-iron than any other country engaged in this industry during the periods under discussion.

Finland

A Spigerverks furnace (Fig. 3) of the latest design was installed at Imatra, Finland, early in 1938. It has an intake of 12,000 k.v.a. and at a 0.90 load factor is capable of producing 30,000 tons per year. Here again agglomerated pyritic residues or "blue billy" is smelted, and the resultant iron is sold under a guarantee of 0.020 per cent. phosphorus and 0.01 per cent. sulphur maximum. This furnace was abundantly satisfactory and represented the last word in the Ivar Hole design. It fulfils the requirements as to being a metal mixer and electric accumulator. This is confirmed by Fig. 3, which shows the elevation of the electrode tip in reference to the furnace bottom, whereby an entire day's run of iron may be stored in the hearth, and tapped out in fractional casts.

General

These comparisons indicate the conditions under which electric smelting is possible, and emphasise the favourable conditions in Norway. They also indicate relative activities in the four countries in which the art has any prominence, and the only continent on which the process has succeeded commercially.

North America

In regard to smelting ore in the western hemisphere, complete failure has occurred in every case. The causes for failure are apparent in each instance and may be attributed to improper furnace designs or to commercial troubles, which developed later.

Canada

The fact that electric current was available in parts of Canada at rates varying between 22s. 6d. and 30s. per horsepower-year led to an interest in the art of electric smelting. A Government commission was appointed, which, under the guidance of Dr. Eugene Haanel, visited various countries in Europe, where experiments were being carried on for finding the proper devices for smelting iron ores electrically. Dr. Héroult was engaged and came to Sault Ste. Marie, Ontario, in 1905. He brought with him the idea of introducing the direct-heating arc furnace, in which he had full confidence. His furnace consisted of a circular steel tank properly lined. One carbon electrode was included in the bottom and the other was suspended from above. The furnace was unenclosed. This electrode suspension led to troubles that were insurmountable and the furnace was abandoned. Haanel tried to obviate these difficulties, and a double furnace was built in which the electrode was more firmly set in place and did not contact the raw materials until they more nearly approached the hearth. Turnbull, in an attempt to embody Dr. Stansfield's "ideal" furnace ideas, then brought forward his complicated direct-heating furnace with six electrodes. This furnace also had a rotating nodulising kiln attached. All these types were failures, although some electric pig-iron was produced during the World War and 27,000 tons was produced as late as 1918. This operation was carried on in steelmaking furnaces by using steel scrap, and the product was a "synthetic" pig-iron.

California

In 1906 Dr. Héroult transferred to Shasta County, California, at the instance of Mr. H. H. Noble, President of the Northern California Power Company, who was trying to find new uses for electric power in addition to having an interest in the excellent iron ore found in that county. This ore contained 68 per cent. metallic iron; the sulphur was 0.021 per cent. and phosphorus 0.012 per cent. Héroult still clung to the direct-heating arc principle, but increased the electrodes to three in number. The closed furnace included five charging stacks, around which the escaping gases were burned. This furnace was guaranteed to make 20 tons per day. It was blown in July 4, 1907, and proved to be a failure in every way. Dr. Dorsey Lyon, after due experimentation, designed a high-shaft furnace essentially the same as the early Elektrometalls furnace, of which the modern furnace (Fig. 1) is the outgrowth. The gases were not recycled, but were burned in the furnace top with air introduced through tuyeres inserted just above the stock line. This furnace operated from 1909 until 1911. The next effort in California was the Noble furnace, designed by Dr. Frickey. A second and larger furnace of the same design was erected in 1913. In principle these two furnaces followed the lines shown in Fig. 4, and the fuel consisted of 60 per cent. coke and 40 per cent. charcoal, both of inferior quality. These three furnaces completed efforts at Héroult on the pit. All ended in commercial disaster, no doubt largely because of a rise in the power rate from £2 10s. to £5 per horsepower-year.

In 1918 another pit-type furnace was built in Shasta County with an output of 1,400 kw., and an effort was made to smelt the same ores previously used. Inasmuch as the costs, according to W. A. Darrah, were nearly £6 at the furnace without overhead, this attempt also ended in failure—and with it electric smelting in California ceased.

British Columbia

The efforts in Canada and California cover the actual attempts at the commercial smelting of iron ores in North America, although Dr. Stansfield prepared a report for British Columbia that indicated a cost of £6 per ton in that province, with electric current delivered at £3 per horsepower-year.

South America

One effort was made in Brazil, which depended upon seasonal power, a condition resulting from the use of the current by the "coffee hullers" during the summer months. This plant was well designed by K. Leander and consisted of two Elektrometalls furnaces, each capable of producing 30 tons per day, in conjunction with two 6-ton converters with adequate rolling-mill capacity. An electric-steel furnace was also included, and may be looked upon as a curer of ills arising from conditions existing at the plant. This company failed in 1929—a failure attributed to the "petering" of the ore supply. This seems anomalous in a country as rich as Brazil is known to be in iron reserves, and other ores were available with a haul of less than 600 miles.

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Sound Film of Alloy Steels' History

A sound film produced by the Bureau of Mines in co-operation with an industrial concern, entitled "Alloy Steels—A Story of Their Development," has been produced for general educational purposes.

Relation of Defects in Enamel Coatings to Hydrogen in Steel

By C. A. ZAPFFE and C. E. SIMS

(*Continued from page* 228.)

A preferential rupture of the cover coat will indicate that the ground coat is more permeable to hydrogen than the cover coat. The pressure centre thus often transfers from the metal-enamel interface to the interface of the two coatings, thereby accounting for the perplexities among enamellers who have tried to find the reason that scales and chips are variously seated in the coating.

An idea of the practically limitless power of precipitating hydrogen may be gained from Fig. 10. Two ½-in. steel plates were cleaned and welded together around their peripheries, heated to 1,200 deg. C. and rolled to a small reduction. Care was taken not to oxidise the interface more than would result from a thin layer of adsorbed air. The compound disc was then pickled in dilute sulphuric acid until blisters

FIG. 10.—BLISTERS IN ½-IN. STEEL CAUSED BY HYDROGEN DERIVED FROM PICKLING.

appeared. From the photograph, it is evident that most of the area of the interface welded together. Where an oxide film remained, however, hydrogen, generated during pickling, was halted during diffusion, and pressures resulted that blistered the steel over these areas. The force required must have been several thousand pounds per square inch.

An apparatus for measuring the pressure developed by hydrogen diffusing into an artificial cavity in steel is shown in Fig. 11. A solid steel cylinder was drilled longitudinally and the open end was fitted with a high-pressure gauge. As cathode in an electrolytic bath, the steel quickly absorbed hydrogen, which diffused through the steel, into the cavity, and there created pressures that increased rapidly and without apparent hindrance from the constantly accumulating back pressure of molecular hydrogen. When 32 atmospheres pressure had been obtained, the gasket around the gauge ruptured and the test was discontinued. Pressures of more than 300 atmospheres have been similarly obtained by other investigators, but such experiments are limited because they become dangerous.

It can be appreciated that the effects of hydrogen in steel are strong functions of time as well as temperature. This is illustrated in Fig. 6, for a coating could obviously be satisfactorily applied if sufficient time had elapsed after pickling. It would be interesting to find the approximate stage of the evolution of hydrogen shown in Fig. 6 at the time the raw enamel is applied. Fig. 12 therefore shows a similar rod which has been given approximately the following standard procedure used to prepare all steels in this research for enamelling:

(1) Wyandotte No. 5 Perfection Cleaner; 4.5 per cent. solution (90 gms. in two litres of distilled water) at 77 deg. C. for 15 mins.

(2) Rinsed in tap water at about 75 deg. C. for 3 mins.

(3) Pickled in 5 per cent. H_2SO_4 solution (85 ml. of H_2SO_4, density = 1.84, in 3 litres of distilled water) at 65 deg. C. for 15 to 30 mins. as required.

(4) Rinsed in tap water at about 75 deg. C. for 3 mins.

(5) 0.5 per cent. Na_2CO_3 neutralising solution (10 gms. anhydrous Na_2CO_3 in 2 litres of distilled water) at 70 deg. C. for 5 mins.

(6) Dried at 115 deg. C. for various periods, as noted.

(7) Sprayed, or dipped, with various enamel slips, as noted.

(8) Baked at 115 deg. C. for various periods, as noted.

(9) Fired at temperatures as noted.

Instead of applying the enamel coating, however, the procedure was interrupted after step (5), and the rod was immersed as before in plain hot water so that the effusion of gas would be made visible. Although appreciably less than that shown in Fig. 6, the effusion is certainly most significant. By changing slightly the temperatures and periods of time of the various parts of the procedure to minimise the hydrogen adsorption during pickling and to provide the dissolved hydrogen with more time to diffuse and more rapid diffusion in post-pickling operations, the results shown in Fig. 13 can be obtained. Here the turbulent effusion has been completed while the specimen was in the neutralising and rinsing baths. As a result, the coating is applied on a surface that no longer evolves gas. This evolution, it will be recognised, comprises only hydrogen, that was atomically dissolved or retained in sub-microscopic rifts.

Enamellers, however, apparently have recognised this type of evolution, and the drying periods before coating and before firing rid the specimen quite effectively of such dissolved hydrogen. Correspondingly, blistering and scaling of enamels has been greatly minimised in recent years. Nevertheless, it has been amply pointed out in the previous discussion that low-temperature annealing will not eliminate occluded hydrogen from the steel, and the best published enamelling procedures still fail to effect complete elimination of defects that are caused by these remanent insoluble portions of hydrogen.

Numerous other experiments have been made to show the astounding effects produced upon steel by hydrogen, but these few should be sufficient to convey the information and significance necessary to appreciate fully the effect of hydrogen in the following experiments with vitreous enamel coatings.

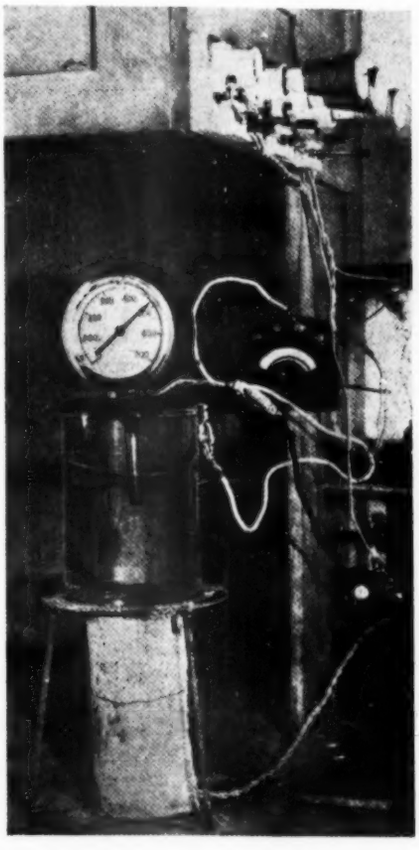


FIG. 11.—GAUGE REGISTERING PRESSURE OF MOLECULAR HYDROGEN TRAPPED IN ARTIFICIAL CAVITY IN A STEEL CYLINDER DURING ELECTROLYSIS.

RELATION OF HYDROGEN IN STEEL TO ENAMELLING DEFECTS

Blistering and Boiling—Introduction

Metallurgical literature contains a redundance of names for the fissures in steel that have recently been shown to be caused by hydrogen. It should not be surprising, therefore, to find that the literature on enamel contains a similar array of defects for which no satisfactory cause or relation has been found. This long list of enamelling defects may be considerably foreshortened and interrelated when considered with an understanding of the anomalous functions of hydrogen in iron and steel.

It has just been explained that any heterogeneity whatsoever in steel, whether it be a fissure, a blowhole, an inclusion, a grain

boundary, or an alloying element, that is metastably held, will collect large quantities of hydrogen and will retain this hydrogen until the steel is heated to some elevated temperature. In the case of sheet-steel enamelling stock, hydrogen will be inherited from the steelmaking process (refer to Fig. 4), and this quantity may be subsequently increased (1) during the scale-removing pickling operations prior to cold working (Fig. 5); (2) during the pickling in the cleansing operation for enamelling (Fig. 12); (3) by ordinary rusting reactions with moisture; (4) during enamel firing by the reaction of the iron with chemically combined moisture in the slip, or with steam in the furnace atmosphere; or (5) by direct absorption from gases in the furnace. The behaviour of occluded hydrogen has been amply discussed, and it is evident that hydrogen, even in a hypothetical, perfectly pure and homogeneous iron wherein occlusion could not occur, still demands careful consideration because diffusion at ordinary temperatures is exceedingly slow and solubility at elevated temperatures becomes very great.

Actual analysis has shown that enamelling stock contains important quantities of hydrogen, and that more will be absorbed during firing. Many present-day writers continue to express gas analyses in weight per cent. and then proceed to dismiss hydrogen as an important consideration because analysis shows less than half as much (by weight) hydrogen as there is nitrogen, oxygen, or carbon dioxide, or because the figure is so insignificant compared with that of iron. Actually in such analyses there is, respectively, 14, 16, 22 and 28 times as much molecular hydrogen as credited (twice these quantities of atomic hydrogen!), and it immediately follows that hydrogen is often the predominating gas by direct analysis. Then the fact should also be considered that important fractions of hydrogen may escape analysis either by diffusion from the steel before the analysis or by virtue of the impotence of vacuum technique, which must operate against a most effective square-root relationship in abstracting at elevated temperatures the now highly soluble gas. In addition, most other gases exist in the steel as solid phases, which do not show the anomalous behaviour that characterises hydrogen; in fact, such solids as oxide inclusions, etc., can hardly be regarded as part of the gas content of the steel, at least of the solid steel, and even in liquid steel an important fraction is present as dissolved solids and as chemical or mechanical suspensions.

It is interesting that the earliest writers on enamelling defects suspected gases contained in the steel to be the source of the defects and that many writers have suspected hydrogen; whereas only during the last few years has proof been advanced that hydrogen is the malefactor, and none of this work appears in English literature. The reasons that hydrogen was not identified long ago are those just mentioned, *viz*: (1) analysis for hydrogen is so difficult that results have always given deceptive minimum values, and (2) analyses have been expressed only in weight per cent. and without regard for simple chemical relations.

Enamellers have published little on hydrogen as a cause of enamel defects. King, for example, dismissed consideration of hydrogen with brief mention of Baker's inconclusive findings in 1918 and a comment on the fact that Hayes, Canfield and McGohan reported finding only 0.0008 weight per cent. of hydrogen in enamelling stock. Atom for atom, hydrogen to iron, there is just fifty-six times as much hydrogen in that analysis as represented so unfortunately by the figure 0.0008 weight per cent. Referring to Fig. 3, it may be seen that a steel containing 0.0008 weight per cent. hydrogen may be stressed beyond its breaking point by this amount of gas; and it is true that steel showing the internal breaks referred to as "flakes" and "shatter cracks" often analyses less than 0.001 weight per cent. hydrogen.

Enamelling stocks contain hydrogen in quantities that vary widely from stock to stock, and these inherent quantities are greatly enhanced during firing by reaction of the iron with chemically combined moisture in the enamel. For example, Kerstan found that stock containing 0.00022 weight per cent. hydrogen before firing, analysed 0.00098 weight per cent. hydrogen after firing. Hoff and Klärding, and Klärding, show that enamel analyses about 1 per cent. H_2O after drying for ten hours at 125 deg. C., and that this combined water is a prolific source of hydrogen to the steel during firing.

It is therefore evident that hydrogen must be considered in regard to enamelling troubles, for, if the gas effuses from the steel during firing at a time when the enamel is in a certain state of pastiness, blisters will be formed in the viscous enamel; if the effusion occurs when the enamel has hardened, the gas will collect under pressure at the enamel-metal interface; and, if the coating is not sufficiently permeable, chipping of the enamel will occur.

The latter type of phenomenon recognises in enamelling as "fishscaling" and possibly "chipping," "jumping," "pop-offs," "crystallites," etc., will be discussed later. Effusion of gas during firing to form blisters in the enamel has been variously dubbed "boiling," "primary boiling," "blistering," "bubbling," and "reboiling," which terms are undoubtedly differentiated much more than is necessary. All are characterised by the formation of blisters in the enamel and are unique principally in the time of their occurrence.

The most discussed of the group is perhaps the "re-boil blister," which often seems to depend on a previous firing for its appearance. The cause of reboiling is admittedly not known, but the accepted explanation in America is that carbon in the iron reduces oxides in the slip during firing to produce gaseous carbon oxides.

Examining the observations contained in the literature on blister-type defects, there is a most

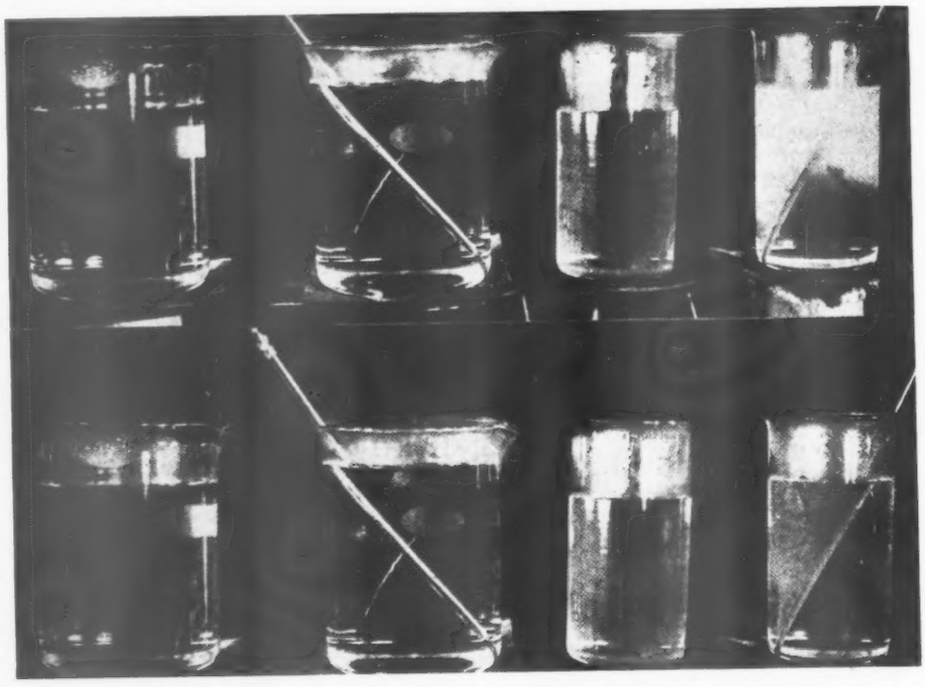


FIG. 12.—ONE-EIGHTH INCH ROD IMMERSED IN WATER (AS IN FIG. 6) AFTER STANDARD PREPARATION FOR ENAMELLING. UPPER: IMMEDIATELY AFTER IMMERSION. LOWER: SIX MINUTES LATER.

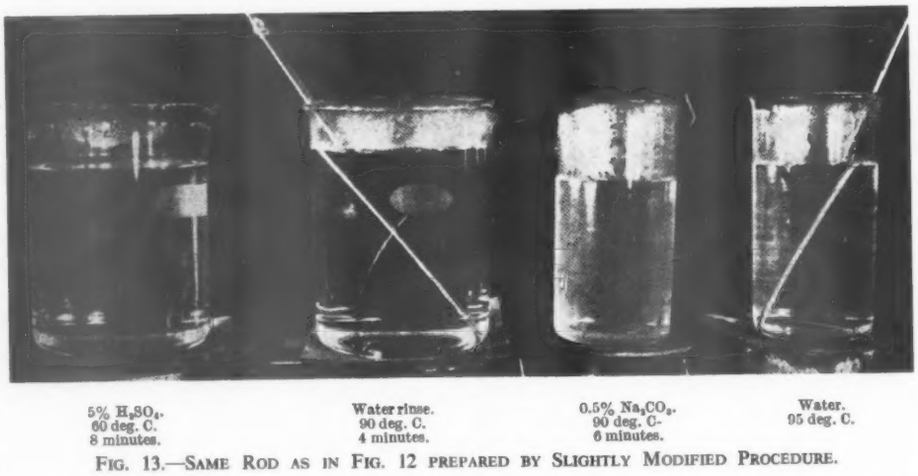
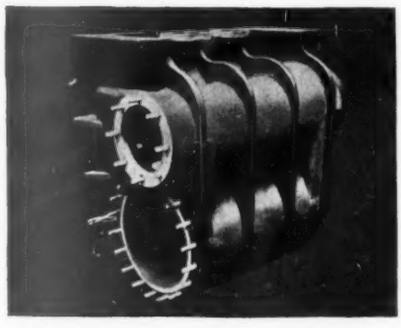
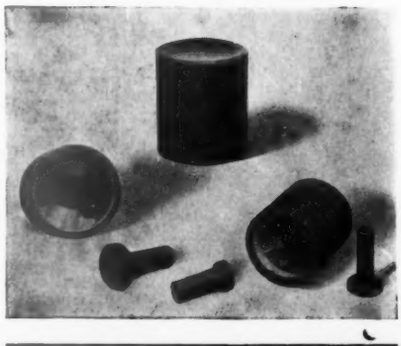
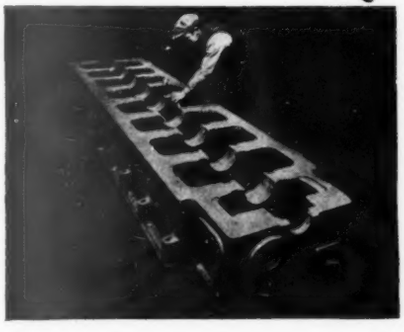


FIG. 13.—SAME ROD AS IN FIG. 12 PREPARED BY SLIGHTLY MODIFIED PROCEDURE.







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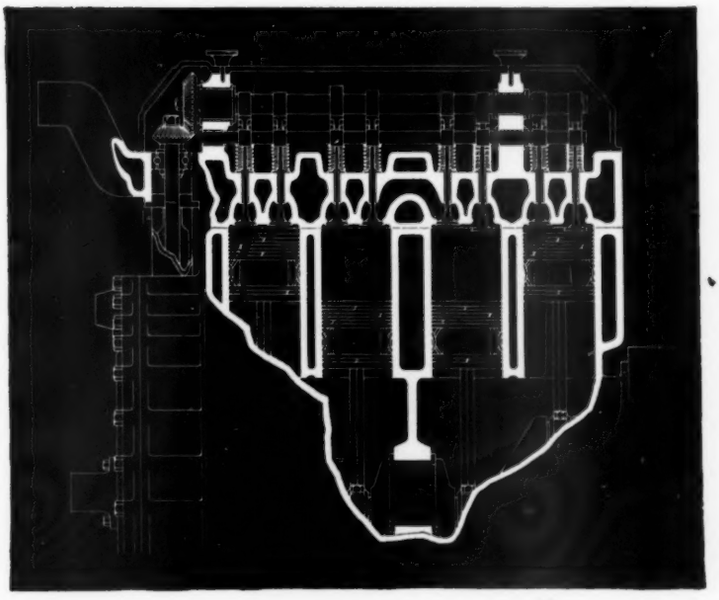

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remarkable congruence with every observation that should be expected if the hydrogen activities previously outlined are understood. Before comparisons are drawn, however, the writers wish it to be understood that they do *not* disclaim the fact that some blistering may result from carbon-oxygen reactions, from liquids that have seeped into surface irregularities, and from other minor reactions and miscellaneous shop defects. The writers contend only that hydrogen is very likely to be the major cause of the blistering that appears during firing porcelain enamels on iron or steel and that, whatever its order of importance, some important functions of hydrogen in enamelling stock have not yet been recognised by the enamelling industry, particularly in this country.

Take, for example, some of the points in the excellent summary on reboiling provided by Lord. First, he states that reboiling commences suddenly as the piece reaches a dull red heat, lasts for a few seconds and then subsides, and *will not occur again until the piece has been first cooled to nearly room temperature.* Such an observation conforms perfectly to the hydrogen theory, for it will be recalled from the work outlined in the first part of this Paper that hydrogen occluded in the steel is released from its localised positions when the steel approaches a dull red heat. Diffusibility is rapid and the solubility remains low while the iron is still body-centred cubic. The released hydrogen will diffuse through the steel and, if near enough to the surface, will effuse at the metal-enamel interface to cause first a wrinkling and then blistering according to simple laws of surface tension. Connelly and Lord observed this process with a suitably arranged microscope, and the inception of blistering that they observed 15 to 40 secs. after inserting 20-gauge stock in a furnace at 875 deg. again conforms with what one should expect from hydrogen diffusing from within the metal. Furthermore, actual spectrographic analysis and microgas analysis showed that hydrogen and its compounds were by far the dominating gases evolved below 650 deg. C. Shortly above this temperature, it will be recalled, the solubility of hydrogen in steel sharply increases (Fig. 1) so that hydrogen freed from occlusion is no longer forced to diffuse out of the steel and may dissolve freely in the iron lattice. Evolution at the metal-enamel interface should then decrease as the temperature increases above 600 or 700 deg. C., and this is precisely what it does. Although many blisters burst from the preliminary heavy effusion as the temperature increases, they are actually observed to collapse without breaking, and the boiling ceases. Re-solution of hydrogen into the iron is especially favoured by the fact that the enamel coating protectively provides an equilibrium atmosphere of almost pure hydrogen on the face of the metal lattice. Bare metal in time would lose its hydrogen by diffusion into the atmosphere. The ease with which the gas goes back into the metal is attested by the observation that in some cases stock enamelled only on one side blisters much less than when enamelled on both sides. Blistering by carbon-oxide gases would scarcely conform to any of these observations.

"Collapse" of Hydrogen

During the remainder of the firing period, the hydrogen is largely in solution in the iron and will remain there until the temperature falls and the functions of diffusibility and solubility reverse to cause the gas once again to precipitate from the iron lattice. In a carbon steel or a steel containing other elements reactive with hydrogen, much of the excess hydrogen conveniently collapses within the steel from four volumes of atomic hydrogen, for example, into one volume of quasi-methane, as has been explained. Other portions of the gas will find their way back into the rifts, inclusions, and grain boundaries from which they originated. An appreciable part will find the metal-enamel interface, of course, and will there diffuse away through the enamel or will create pressures sufficient to rupture the enamel in a type of defect recognised as "fishscaling."

Hydrogen Replenishment

The enamelled specimen is now in precisely the same condition with regard to hydrogen as it was before the first firing, except that a portion of the original hydrogen has been lost. Although additional hydrogen is often absorbed by the steel during the first firing, as previously explained, successive firings will progressively remove hydrogen in the foregoing manner; it is also interesting to note that after 20 to 25 heatings reboiling will no longer occur. The analogy in metallurgy is well known.

The replenishment of hydrogen that is provided by reactions of the steel with steam in the furnace atmosphere or with chemically combined moisture in the slip should be quite well understood. To form *one* molecule of the black, magnetic iron oxide that may largely constitute the "hazy layer" in enamel and that is thought by some to be related to blistering in cast-iron enamelling, *eight* molecules of atomic hydrogen are liberated according to the reaction,

$$3Fe + 4H_2O = Fe_3O_4 + 8H.$$

Likewise, the formation of ferric oxide, Fe_2O_3, liberates *six* relative molecules of atomic hydrogen. Most important is that the liberation occurs in contact with hot steel, where chances for solution of such nascent hydrogen would be excellent even at low temperatures. It is significant that a great deal of importance has been attached to this oxide-containing "hazy layer," for without it there is poor adherence, and Howe and Fellows record that the more vigorously an enamel boils, the better the adherence. There is no need to believe that the iron oxide results from reduction by the iron of refractory oxides in the enamel when reaction with moisture is so much more feasible, for no matter how carefully the slip is dried, about 1 per cent. by weight of moisture will remain until a temperature of about 800 deg. C. is reached and this combined water is released. In addition to this moisture, steam in the furnace atmosphere is most effective and has often been shown to cause bad blistering even when present only in amounts of 5 or 10 per cent., whereas the addition of oxygen to the atmosphere has no effect. Again, irons and steels that blister in ordinary atmospheres will not blister when fired in nitrogen, very likely because hydrogen, not oxygen, is absent. Carefully venting the firing furnace is common practice to avoid blistering, which again must be due to the removal of hydrogen and not of oxygen.

(To be continued.)

(Continued from next column.)

by the Research Officer. A presentation was made to the previous Secretary.

An extraordinary general meeting was held on July 9, at which an amendment to the Institute's articles of association was approved. This has the effect of making all ordinary members eligible for election to the Council, irrespective of their business connections. In accordance with this provision a number of candidates previously not eligible have this year been nominated.

In conclusion, Mr. Whittle thanked Mr. J. W. Gardom for his services as convener of the Joint Technical Committee.

Prof. J. H. Andrew was re-elected President, and, as a result of a postal ballot, the following were elected:—As treasurer, Mr. W. S. Grainger: as members of council, Mr. W. Todd, Mr. W. Thomas and Mr. C. Baines.

Institute of Vitreous Enamellers

ANNUAL GENERAL MEETING

The annual general meeting of the Institute of Vitreous Enamellers was held in Birmingham on October 2. Mr. W. H. Whittle, the chairman, presided, and presented the following report.

Chairman's Report

The Institute has survived well the first year of war, indicating that although conditions in the industry have deteriorated considerably, the members still desire to keep and work together, and not to sacrifice the good work already done by the Institute. This attitude will in the long run be of benefit to all members.

Membership has been well maintained, the few resignations being balanced by new members. The war has brought great changes, and the Institute has lost touch with a few of its members. Others are serving with the Forces, and the Council has ruled that they should not be asked for subscription. The total membership is now 216, comprising 93 companies, 65 members, 33 associate members, and 25 associates.

Meetings have not been held so frequently, but two of the sections had managed to carry on. The Midland Section has held one meeting, and the Southern Section three, of which the outstanding one was the Exhibition Meeting, which was preceded by an exhibition of vitreous enamelled products and materials, and apparatus used in the industry. No works visits have, however, taken place. The war caused the 1939 annual conference to be abandoned and no arrangements were made for one this year. No definite programme has as yet been finally arranged for next session, but members will be kept informed by circular as previously used.

Co-operation with Other Bodies

Although members have not been able to be so active in Institute affairs as formerly, the Institute as a body representing the industry has been consulted by and has co-operated with a number of official bodies and departments, including the Ministry of Supply, the Petroleum Board, the Stores Inspection Department, the British Standards Institution and the British Colour Council, thus amply justifying its existence and aims.

Among publications distributed to members was the fifth Annual Proceedings, and the sixth volume will soon be available. "Enamelling Abstracts" was circulated quarterly, and provides a useful record of published literature, the value of which would increase with time. A special publication, the "Glossary of Terms in Use in the Vitreous Enamelling Industry," has been circulated and has aroused interest also in other quarters.

A considerable extension of the research programme had been planned, but it has not been found possible to put this into operation on the lines intended. Members naturally find it difficult to attend Committee meetings, although interested and willing to give their support where work of national importance does not occupy all their time. This problem is still under consideration, and it is hoped that other arrangements can be made.

The Chemical Resistance Test Sub-Committee has concluded its work on a test for finished enamelware, and a further comprehensive report is in its last stages and will shortly be available.

On account of the possibility of reduced income, arrangements were made with the B.C.I.R.A. for the Institute's contribution to be reduced. Also, on the resignation of the Hon. Secretary, the secretarial work was undertaken

(Continued in previous column.)

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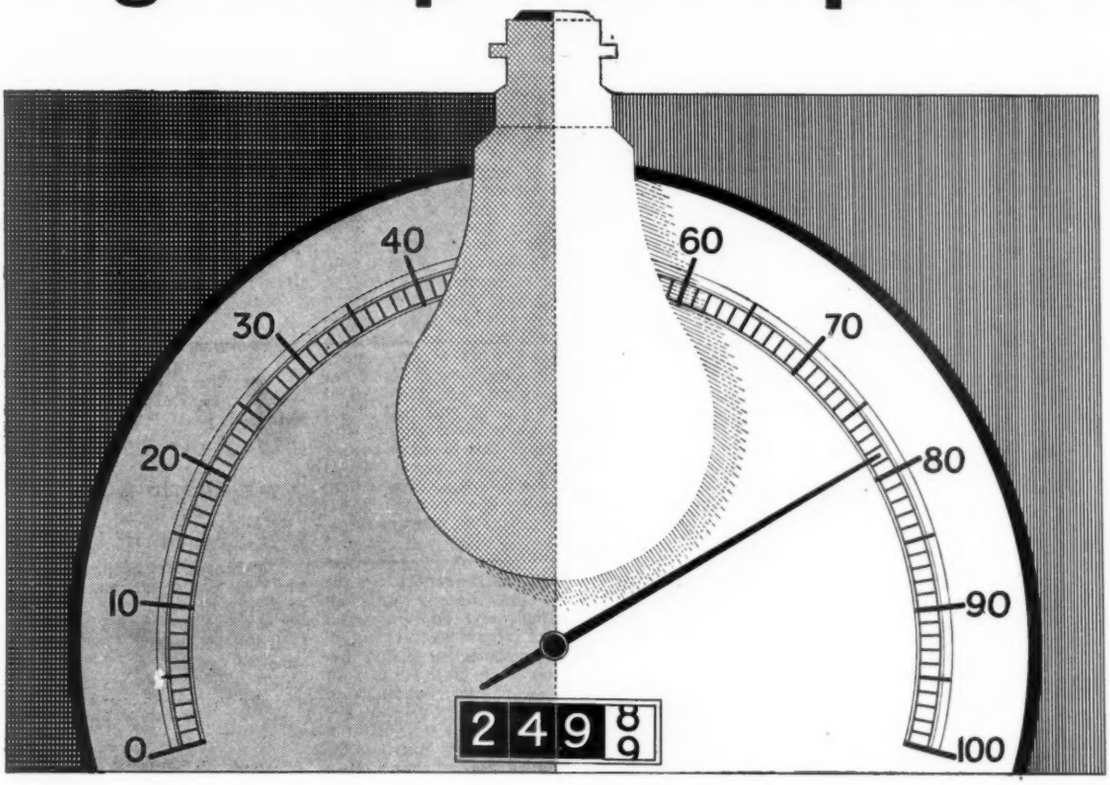

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The Week's News in Brief

Trade Talk

THE MINISTRY OF SUPPLY states that splinters from anti-aircraft shells are a valuable form of scrap metal. Nose-caps are also of value. "Shrapnel" boxes in offices and workshops are suggested.

ACCORDING TO AN OFFICIAL STATEMENT from Capetown, the Union of South Africa is now exporting iron ore to the United Kingdom to make up for the closing of the Swedish trade. This trade has expanded rapidly during recent months.

THE MINISTER OF WORKS and Buildings has appointed Mr. Hugh Beaver to be Priority Officer and Controller of Building Materials. It is intended immediately to apply control to cement and bricks, and these sections will be respectively directed under the Controller, by Lord Wolmer, M.P., for cement, and Mr. T. P. Bennett for bricks.

THE FIRM OF James Dobbie & Company, ironfounders, of Banknock Foundry, Bonnybridge, has been dissolved following the death of Mr. Thomas Scott Dobson, one of the partners. The business will be carried on by the remaining partner, Mr. George Ure Dobbie, on his own account under the existing name.

THE U.S. rearmament programme is not likely to require more than 7,000,000 tons of steel in the peak year, stated the chairman of the Inland Steel Company, at the annual meeting of the Association of Iron and Steel Engineers. He believed that less than one-fifth of the steel business (including exports) will probably be war created, and prices should show no great change.

THE FOLLOWING FIRMS have been elected members of the British Cast Iron Research Association; in brackets are given the names of the firm's representatives:—Clyde Engineering Company, Limited, Granville, N.S.W., Australia (Mr. E. Ashworth); Gimson & Company (Leicester), Limited, Leicester (Mr. J. B. Curry); Frederick Parker, Limited, Leicester (Mr. A. D. Parker); and Taylor & Farley, Limited, West Bromwich (Mr. F. A. W. Fidler).

THE United States Steel Corporation has declared a dividend of $1 per common share of no par value. The regular quarterly payment of $1.75 on the 7 per cent. cumulative preferred $100 shares is also announced. Both in March and July last a dividend of $1 per common share was declared. The total distribution for 1940 is thus $3, compared with nil in each of the previous two years and $1 in 1937, when common dividends were resumed after a lapse of five years.

THE REGISTERED and general offices of George Cohen, Sons & Company, Limited, have been transferred to Broadway Chambers, Hammersmith, London, W.6, to which address all correspondence concerning the company's accounts department, scrap iron department, dismantling department, shipping department, and railway department should now be directed. The company's non-ferrous metals department, as well as the wharf for handling dealers' trade in all types of metals, will, however, be maintained at 600, Commercial Road, London, E.14, as heretofore.

CLASSES HAVE NOW BEEN established for training in roof-spotting at over 100 centres in different parts of the country. To cover the whole of industry as quickly as possible, it is intended to allot vacancies to one representative of each firm desiring training; this representative will then be in a position to train the roof-spotting team of his firm. Courses will last five days. Firms desiring training should apply to their local A.R.P. Controller, whose address can be obtained from the Town or County Hall or from the local Council Offices. Full particulars of the arrangements will be supplied and vacancies allotted at the earliest possible moment.

THE Select Committee on National Expenditure has adopted as its 14th report the proposals of a sub-committee for improving the present camouflage technique. The sub-committee is not satisfied with the rate at which vital industrial points are being camouflaged. Cases have been brought to the notice of the sub-committee where private practitioners have camouflaged industrial premises. Some of these attempts have been certainly futile and might be dangerous, and the sub-committee learns with satisfaction that most of these private firms have gone out of existence. It does not, however, regard it as satisfactory that the "possibility of such maladroit attempts continuing to be made still exists." It therefore recommends that owners of industrial enterprises who, though not required by law to camouflage their concerns, yet desire to do so, should be encouraged to seek the guidance of the official camouflage organisation.

A STATEMENT issued by the Canadian Government and quoted by VISCOUNT CRANBORNE, the Dominion Secretary, in the House of Commons, says that since the outbreak of the war, the export to all destinations of essential metals and minerals from Canada has been subject to direct control, and individual export permits have been required for each shipment. No export permits have been granted when there was any reason for believing the goods would directly or indirectly fall into enemy hands, and no permit has been granted for the export of any product of which Empire and Allied supplies fell short of requirements. In pursuance of this policy, no scrap iron or steel has been exported from Canada since October, 1939, and there has been no export from Canada, except to the United Kingdom, Allied countries and the United States of zinc and nickel since February, of aluminium since April, and of cobalt since August. Shipments of other metals and minerals from Canada to destinations outside the British Empire and the Western Hemisphere have been kept within the limits of normal peacetime trade with the other countries concerned.

MR. A. CALLIGHAN, of Middlesbrough, general secretary of the National Union of Blast-furnacemen, alluding in his half-yearly report to the negotiations for treating the air-raid warnings merely as an "alert" signal, says he appreciates the members' desire that the largest possible output should be produced at their respective plants, but the cessation of production at a blast furnace or coke-oven plant is a different proposition from the cessation of production at a workshop or factory where the machinery can be stopped at a moment's notice, thus immediately freeing the workpeople from their duties and enabling them to proceed right away to the air-raid shelters provided for them. If this point is appreciated by those in authority at the various plants—and it is in the great majority of cases—then the members will accept, without demur, the risks arising out of war conditions. But it is a point which must not be ignored. It is therefore desirable that on this question of air-raid precautions there should be the fullest possible co-operation and consultation between the firm and the official representatives of the union if the best results are to be obtained. Alluding to the establishment of Regional Committees to deal with any emergency which may arise at any blast furnace or coke-oven plant, Mr. Callighan says that it safeguards the national agreement of the industry, and the ironmasters have now the assurance that if an emergency arises it will be dealt with promptly and effectively.

Obituary

MR. CHARLES ROSS, of Charles Ross, Limited, structural engineers, Heeley Bridge Engineering Works, Sheffield, died recently, aged 64. Mr. Ross was a son of the founder of the business.

MR. EDWARD DIXON, sales director of Thos. Firth & John Brown, Limited, Sheffield, has died at his home at Worksop. He was aged 69. In July, Mr. Dixon completed 50 years' service with the company, and was presented with his portrait in oils. A member of a well-known Sheffield family, Mr. Dixon joined the firm in 1890. This was his first business appointment. He spent the first four years in obtaining a thorough insight into, and technical knowledge of, the firm's business, after which he spent some time studying steelworks' methods in France. Returning to the works in 1895, he was given charge of one of the departments and in 1909 he was appointed works manager of the gun department, later becoming general manager and director in charge of the department. Mr. Dixon took his seat on the board of the company in 1920, from which time he devoted special attention to the sales side of the company's organisation. Mr. Dixon was associated with "Engineering," of which he was chairman for the past 11 years.

Personal

CAPT. OLIVER LYTTELTON has resigned from the board of Lightalloys, Limited, on his appointment as President of the Board of Trade. Mr. W. H. Grieve, managing director, has been appointed chairman in his place.

Wills

CROMPTON, COL. R. E. B., of Crompton Parkinson, Limited	£28,329
EUNSON, DAVID, of Glasgow, director of P. W. MacLellan, Limited	£5,509
CHANCE, G. B., departmental director of E. J. & J. Pearson, Limited, firebrick manufacturers, Stourbridge	£8,095
ODDIE, W. M., managing director of Spencer & Halstead, Limited, and John Ingham & Sons, Limited, engineers, of Ossett	£23,218

Contract Open

Birmingham, November 11—Supply and erection of cast-iron water-pipework (up to 8 in. dia.), etc., for the Town Council. Mr. F. Forrest, chief engineer, 14, Dale End, Birmingham, 4. (Fee £2, returnable.)

Applications for Trade Marks

The following list of applications to register trade marks has been taken from the "Trade Marks Journal":—

"BRICROME"—Castings, metal liners and sleeves, etc., all containing chromium. BRITISH PISTON RING COMPANY, LIMITED, Holbrook Lane, Coventry.

"NONVAR"—Steel. THOS. FIRTH & JOHN BROWN, LIMITED, Atlas and Norfolk Works, Savile Street, Sheffield.

Forthcoming Events

NOVEMBER 13.
Manchester Metallurgical Society:—"Jointing of Metals," Paper by Dr. J. H. Paterson, at Manchester, at 6.30 p.m.

Institute of British Foundrymen

NOVEMBER 12.
Burnley Section:—"One Way of Making a Loam Mould," Paper by J. Potter, at Burnley, at 7.30 p.m.

NOVEMBER 15.
Sheffield Branch:—Presidential address by Malcolm Brown, "Things That Have Interested Me," followed by a discussion, at Sheffield, at 7 p.m.

NOVEMBER 16.
East Midlands Branch:—"Randupson Process of Cement Moulding," Paper by F. W. Rowe, at Derby.

Stocks of
BLACKLEAD
PLUMBAGO
TERRA FLAKE
VAUGHAN, JONES & CO.
8, UNION STREET, LIVERPOOL, 3

A Refractories Industry within one organisation

The spectacular achievements of industries which use refractories tend to overshadow the remarkable development of refractory materials during recent years. Higher temperatures and increasingly severe operating conditions have long since deposed "rule-of-thumb" methods of manufacture. Research—applied by the refractories industry, by manufacturers (such as General Refractories), and by users—has developed a range of refractories which are, at least, abreast of to-day's metallurgical processes and plant design. Unrivalled supplies of raw materials—the employment in its many works of modern plant and equipment—the services of leading technicians, operating in works bearing names familiar to all users—and supported by a wealth of practical experience—enable General Refractories to operate a complete refractories industry inside one organisation. And, influencing all activities, controlling production and future development, is "G.R." Research. In modernly equipped laboratories a team of qualified chemists and engineers build into each "G.R." product that consistently uniform quality which is the basis of low operating costs and long dependable service.

GENERAL REFRACTORIES LTD.

HEAD OFFICE: GENEFAX HOUSE, SHEFFIELD, 10. TELEPHONE 31113 (6 LINES)

G.P.I.

FIREBRICKS: *Glenboig Special, Glenboig Special Crown, Glenboig, Glenboig Crown, Castlecary, Dykehead, Gem, White Carr, Stour, Hycone, Alumantine, Hysilyn, Adamantine, Llangennech.*
BASIC BRICKS: *Spinella, Saxpyre, Supermag, Diazite, Dolomax.*
ACID-PROOF REFRACTORIES: *Obsidianite, Losol.*

INSULATION: *Amberlite* Bricks, Cement and Concrete.
SILICA BRICKS: *Lowood, Meltham, Allen, Quartex.*
CEMENTS: *Sintex, Durax, Pyrolyte.* PLASTICS: *Durax, Rotaline, Plastic K-N., Glendoline, Ground Ganister.*
SILLIMANITE: Tank Blocks, Bricks and Cements.
SANDS: Moulding, Brick Facing, Silica, Glass.

Raw Material Markets

NEW SCHEDULE OF IRON AND STEEL PRICES

Prices of iron and steel were increased as from November 1; the new rates will be found in detail in the Price List on page 14, and were contained in the Control of Iron and Steel (No. 13) Order, 1940, made by the Minister of Supply. The price of foundry pig-iron has been increased by 8s. per ton, hematite by 7s. 6d., and basic iron by the same amount. The maximum prices represent a rise of 35s. per ton on billets, sections, joists and rails, and of 40s. a ton on plates, with corresponding adjustments in the quotations of other finished products. Steel castings have been increased by 7s. 6d. per ton and iron castings subject to control are also higher in price. In the case of steel castings the new Order states that prices shall be those "set out in the Related Schedules with the addition of 9 per cent. plus 25s. per ton" (9 per cent. plus 17s. 6d. previously). Prices of cast-iron rainwater and soil goods, gutters and connections, are to be those "set out in the Related Schedules with the addition of 18½ per cent." (previously 8 per cent. plus 20s.). Once again, the major portion of these advances will be devoted to the central fund, which is used to equalise the cost of imported steel and raw materials with the prices of similar home products. An allowance of about 5 per cent. of present prices has been made to meet certain increases in home production costs.

Under the Export of Goods (Control) (No. 37) Order, issued by the Board of Trade, which comes into force to-day (November 7), licences will be required to export to any destination the following classes of goods:—Colliery arches and pitprops; girders, beams, joists and pillars, whether fabricated or not; hoop and strip; plates and sheets of all kinds; railway springs, laminated or coiled; wheels, tyres and axles, whether assembled or not; fishplates and sole plates; wire nails and wire staples, but not including machine staples and insulated staples; wire netting, wire fencing and wire mesh. Applications for licences should be made to the Controller, Export Licensing Department, Inveresk House, 346, Strand, London, W.C.2.

Pig-Iron

MIDDLESBROUGH—The foundry iron requirements of local consumers continue to be met satisfactorily by Midland producers and large consignments are arriving regularly at consuming points. The output of Cleveland foundry numbers is still not on a scale sufficiently large to assist in coping with the demand, but at present the extensive production of this type of iron is not possible in view of the heavy calls on steelmaking irons. Imports of hematite are necessary to supplement the output of East Coast iron, and it is satisfactory to report that adequate tonnages are forthcoming from overseas. Makers in this area are operating their plant at full capacity, and the output of existing furnaces is gratifying if it does not fully cover the heavy demand. A large proportion of the make is, of course, absorbed by the producers themselves, so that importations are imperative, as it is not easy to expand production. The shortage of a few weeks ago has been overcome to a large extent, however, and consumers are receiving much better deliveries. The increases in prices have been received as a matter of course, as it was appreciated that circumstances called for an upward movement in quotations.

LANCASHIRE—Despite the increased use of scrap, demand for foundry iron from users in this area remains at a high level, especially from consumers engaged on Government contracts, such as those in the speciality engineering section. Jobbing foundries are not so active as they might be and the call for supplies from these concerns has tended to contract, while the light-castings trade cannot report much improvement, although a few firms which have been fortunate enough to secure some share in orders of national importance naturally are slightly better placed than others relying solely on ordinary domestic business, which has reached a low ebb. Makers of textile machinery are taking up moderate supplies of foundry iron. There is a strong call for hematite, but deliveries have not been so free as could be desired.

MIDLANDS—In view of the higher costs of production of iron and steel and the need for maintaining imports above the peacetime level, the introduction of higher selling prices occasioned no surprise. Trade among the light-castings foundries is expanding slowly week by week, and more and more works are acquiring orders from Government departments, although the amount of official work so far placed has perhaps been disappointing and quite insufficient to make up for the large volume of business lost through wartime conditions. The requirements of the building trade, especially, have fallen away since the outbreak of hostilities, but it is noticeable that there has been some improvement in this connection during the past week or two. Light-castings makers use high-phosphorus iron in the main and adequate supplies are available to meet their limited requirements. Heavy engineers continue to be employed on work of national importance, and order-books are filled over some time ahead, with the prospect of replacement orders being promptly secured. Owing to the restricted output of low-phosphorus iron and hematite at home sources, large consignments of both descriptions have been, and are still being, imported by the Control authorities, so that the position has improved considerably of late.

SCOTLAND—There is still no opportunity for pig-iron consumers to build up reserve stocks, as, while licences are being issued quite freely, these are for current requirements only. Little or no inconvenience is being caused to users, however, as deliveries are coming to hand regularly. The most active consuming branch continues to be the heavy engineering trade, which is calling for very large tonnages. The position of the light-castings makers, though still not satisfactory taken as a whole, is improving, and certain producers who have been able to adapt their plant to cope with Government orders are operating their works at a higher level than for a long time past.

Coke

Quite brisk conditions continue to prevail in the foundry-coke trade, with home consumers taking up large supplies to satisfy their immediate needs, most of them having already accumulated useful reserves which they desire to retain intact unless deliveries from the ovens fall behind schedule. Now that prices of iron and steel have been raised, it is likely that an early announcement will be made concerning coke prices. The present quotation for Durham best foundry coke is 55s. 6d. per ton, delivered Birmingham and Black Country stations.

Steel

While home sources of production are being pressed for all the steel that can be obtained, outputs remain well below the actual needs of the war machine, and very substantial tonnages are being imported from the United States. In this connection it is of interest to note that the value of iron and steel imported into the United Kingdom in the month of September was no less than £5,103,000, against £1,164,000 a year previously, when Belgium was the principal source of imported material. While every ton of steel brought into the country from overseas is required for essential purposes connected with the national war effort, the cost of such imports is imposing a considerable burden on the industry, and it is largely to meet this that the recent price increases were introduced. Supplies of raw materials are coming to hand in sufficient tonnages to enable works to produce to capacity.

Scrap

Descriptions of scrap used by foundries are plentiful. In fact, with few exceptions, all grades of iron and steel scrap are now available much more freely than was the case a few months ago, and consumers and merchants are making full use of the opportunity to build up stocks. Dealers have large tonnages on their hands which they would be glad to dispose of, but outlets now appear to be somewhat restricted. Actually, consumption is maintained at a good level, but many users are reluctant to increase their commitments until they have relieved the congested state of their yards. The Ministry of Supply has opened a new voluntary scheme to encourage the private owner to give up railings for the scrap-metal campaign. A start has been made in the Midlands, with Birmingham as a centre, and the scheme will later be extended to other districts.

Metals

It has been announced that Sir Andrew Duncan, Minister of Supply, is arranging in the near future to receive a deputation from the London Metal Exchange Committee to discuss various aspects of the Non-Ferrous Metals Control. It is felt that such a meeting may go far towards clearing up several problems which have confronted members of the Exchange in the past.

The feature of the tin market during the past week or so has been the failure of prices to respond in the manner expected to the commencement of the issue of November export licences to the United States by the British Government. In fact, the market has been dull, trade demand here having been only small. It seems that licences have been granted more sparingly than was anticipated would be the case when the Ministry of Supply announced in September that export licences would be granted more freely for shipments during November and onwards. A meeting of the International Tin Committee is due to take place on November 26, but in view of the fact that production is virtually unrestricted no quota decision will be made. Discussion will doubtless be concerned with the progress of shipments to America and the plans of the United States Government to establish a smelter.

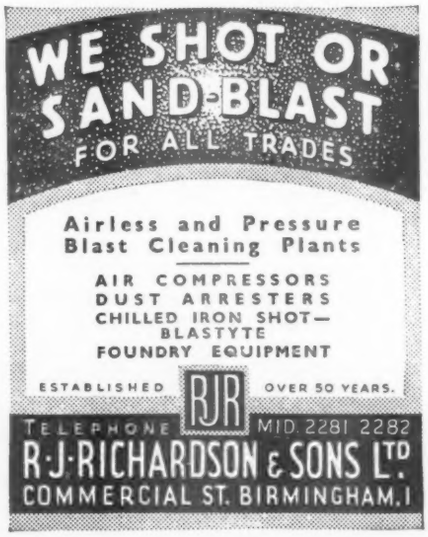
London Metal Exchange tin prices this week have been as follow:—

Cash—Thursday, £259 to £259 10s.; Friday, £258 to £258 5s.; Monday, £258 to £258 5s.; Tuesday, £257 10s. to £257 15s.; Wednesday, £258 to £258 10s.

Three Months—Thursday, £261 5s. to £261 10s.; Friday, £259 15s. to £260; Monday, £260 to £260 5s.; Tuesday, £259 15s. to £260; Wednesday, £260 to £260 5s.

Large arrivals of Empire copper continue to be reported, but the bulk of this metal is absorbed by Government defence requirements. The brisk activity of the United States market has been fully sustained. U.S. copper exports during September totalled 11,729 short tons, of which Japan took 9,269 tons, Great Britain 1,200 tons, China 355 tons, and Sweden 250 tons.

The heavy demand for spelter on Government account is leaving only comparatively small tonnages available for other purposes, but it is gratifying to note that ample supplies are coming to hand for defence uses. The lead supply position is exceedingly good, and a certain amount of export business is being carried on.



ALUMINIUM ALLOYS
and the Foundryman

The swift march of engineering progress demands an ever increasing degree of efficiency in foundry production ... That is why more and more foundrymen rely upon International Alloys Ltd. as their best source of supply for all Aluminium Alloys. They know that the metals produced by this organisation consistently conform to specification.

INTERNATIONAL ALLOYS LTD
SLOUGH, BUCKS

TELEGRAMS: INTALLOYD, SLOUGH TELEPHONE: SLOUGH 23212

RAW MATERIALS—PRICE LIST

Wednesday, November 6, 1940

COPPER*

	£	s.	d.
Electrolytic	62	0	0
High-grade fire-refined	61	10	0
Fire-refined of not less than 99.7 per cent.	61	0	0
Do., do., 99.2 per cent.	60	10	0
Black hot-rolled wire rods	65	10	0

TIN

	£	s.	d.
Standard cash	258	0	0
Three months	260	0	0
Settlement	258	5	0
Official average Cash, Oct.	258	3	0 4/23
Do. Three Months, Oct.	260	10	3 21/23
Do. Settlement, Oct.	258	2	9 21/23

SPELTER*

	£	s.	d.
G.O.B. (foreign) (duty paid)	25	15	0
Do. (domestic)	26	10	0
"Prime Western"	26	10	0
Refined and electrolytic	27	5	0
Not less than 99.99 per cent.	28	15	0

LEAD*

	£	s.	d.
Good soft pig lead (foreign) (duty paid)	25	0	0
Do., do., (Empire and domestic)	25	0	0
English	26	10	0
Sheets, home	34	10	0
Do. export, f.o.b.	30	0	0
Pipes, home	34	0	0
Do. export, f.o.b.	30	10	0
Tea lead (nom.)	—		

ALUMINIUM

Ingots	£110
Wire, 10g.	nom.
Sheets	nom.
Circles, 20/24g.	nom.

ZINC SHEETS, etc.

	£	s.	d.
Sheets, 10g. and thicker, ex works	39	2	6
Rolled zinc (boiler plates), ex works	37	2	6
Zinc oxide (Red Seal), d/d buyers' premises	28	7	6

ANTIMONY

	£	s.	d.		£	s.	d.
English, 90%, delivered	90	0	0				
Foreign Regulus, duty paid	90	0	0	to	93	0	0
Chinese, prompt shipment, c.i.f.	78	0	0	to	82	0	0

QUICKSILVER

Quicksilver, ex-w'hse London 50 0 0 to 54 10 0

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten 3s. 0d.
Finished bars, 18% tungsten 3s. 10d.
Finished bars, 22% tungsten 4s. 4d.
Per lb. d/d buyers' works.

NICKEL SILVER, etc.

	Per lb.
Ingots for raising	9d. to 1/3
Rolled—	
To 9 in. wide	1/3 to 1/9
To 12 in. wide	1/3½ to 1/9½
To 15 in. wide	1/3½ to 1/9½
To 18 in. wide	1/4 to 1/10
To 21 in. wide	1/4½ to 1/10½
To 25 in. wide	1/5 to 1/11
Ingots for spoons and forks	9d. to 1/5½
Ingots rolled to spoon size	1/- to 1/8½
Wire round—	
to 10g.	1/6½ to 2/1½

with extras according to gauge.

Special 5ths quality turning rods in straight lengths, 1/5½ upwards.

* Maximum prices per long ton delivered to buyers' premises.

FERRO-ALLOYS AND STEEL-MAKING METALS

(all prices nominal.)

	£	s.	d.
Ferro-silicon (5-ton lots)—			
25%	18	10	0
45%	23	10	0
75%	36	10	0
Ferro-vanadium—			
35/50%	15/6 lb. Va.		
Ferro-molybdenum—			
70/75% carbon-free	6/- lb. Mo.		
Ferro-titanium—			
20/25% carbon-free	1/9 lb.		
Ferro-tungsten—			
80/85%	5/1 lb.		
Tungsten metal powder—			
98/99%	5/2½ lb.		
Ferro-chrome—			
2/4% car.	—		
4/6% car.	47	0	0
6/8% car.	47	0	0
8/10% car.	—		
Ferro-chrome—			
Max. 2% car.	—		
Max. 1% car.	—		
Max. 0.5% car.	—		
70% carbon-free	—		
Nickel—99.5/100%	£190 to £195		
"F" nickel shot	175	0	0
Ferro-cobalt, 98/99%	8/9 lb.		
Metallic chromium—			
96/98%	3/9 lb.		
Ferro-manganese—			
76/80% loose	18	10	0
76/80% packed	20	0	0
Metallic manganese—			
94/96% carbon-free	1/9 lb.		

Per ton unless otherwise stated, basis 2-ton lots, d/d Sheffield works.

SCRAP*

	£	s.	d.		£	s.	d.
SOUTH WALES—							
Short heavy steel, not ex. 24-in. lengths	3	16	6	to 3	19	0	
Heavy machinery cast iron			4	6	6		
Ordinary heavy cast iron			4	1	6		
Cast-iron railway chairs			4	6	6		
Medium cast iron			3	17	9		
Light cast iron			3	13	0		
MIDDLESBROUGH—							
Short heavy steel	3	14	3	to 3	16	9	
Heavy machinery cast iron			4	11	3		
Ordinary heavy cast iron			4	8	9		
Cast-iron railway chairs			4	8	9		
Medium cast iron			3	19	0		
Light cast iron			3	14	0		
BIRMINGHAM DISTRICT—							
Short heavy steel	3	9	3	to 3	11	9	
Hematite ingot mould			5	10	9		
Heavy machinery cast iron			4	11	9		
Ordinary heavy cast iron			4	7	0		
Cast-iron railway chairs			4	7	0		
Medium cast iron			3	19	9		
Light cast iron			3	14	9		
SCOTLAND—							
Short heavy steel	3	14	0	to 3	16	6	
Heavy machinery cast iron			4	13	9		
Ordinary heavy cast iron			4	8	9		
Cast-iron railway chairs			4	13	9		
Medium cast iron			3	16	9		
Light cast iron			3	11	9		

* Delivered free to consumers' works in England and Wales. For deliveries of cast-iron scrap free to consumers' works in Scotland, the above prices less 3s. per ton, but plus actual cost of transport or 6s. per ton, whichever is the less. All prices: Plus 2½ per cent. dealers' remuneration: 50 tons and upwards over three months 2s. 6d. extra.

PIG-IRON*

N.E. COAST (d/d Tees-side area)—	
Foundry No. 1	131/-
„ No. 3	128/-
„ No. 4	127/-
Forge No. 4	127/-
Hematite No. 1	138/6
Hematite M/Nos.	138/-
N.W. COAST—	
Hem. M/Nos. d/d Glasgow	138/6
„ d/d Birmingham	150/-
MIDLANDS (d/d Birmingham dist.)—	
Staffs No. 4 forge	129/-
„ No. 3 fdry.	130/-
Northants forge	126/6
„ fdry. No. 3	127/6
„ fdry. No. 1	130/6
Derbyshire forge	129/-
„ fdry. No. 3	130/-
„ fdry. No. 1	133/-
Phosphorus 0.5% to 0.75%	137/6
Phosphorus 0.1% to 0.5%	140/6
SCOTLAND—	
Foundry No. 1, Grangemouth	127/3
„ No. 3, Grangemouth	124/9
Cleveland No. 3, Glasgow	131/-
„ „ Falkirk	128/-
Scottish hem. M/Nos. d/d	138/6
SHEFFIELD (d/d district)—	
Derby forge	126/6
„ fdry. No. 3	127/6
Lincs forge	126/6
„ fdry. No. 3	127/6
W.C. hematite	144/-
LANCASHIRE (d/d eq. Man.)—	
Derby fdry. No. 3	133/-
Staffs fdry. No. 3	133/-
Northants fdry. No. 3	131/6
Cleveland fdry. No. 3	133/-
Cylinder and Refined Irons	
North Zone	174/-
South Zone	176/6
Refined Malleable	
Birmingham and S. Staffs	171/6
Cold Blast	
South Staffs	220/6

* Prices of hematite and basic pig-iron, and of foundry and forge iron with a phosphoric content of not less than 0.75 per cent., are subject to a rebate of 5s. per ton under certain conditions.

SEMI-FINISHED STEEL

Re-rolling Billets, Blooms and Slabs.

	£	s.	d.
BASIC:			
Soft, u.t., 100-ton lots	12	5	0
Tested, up to 0.25% C.	12	10	0
Tested, 0.25 to 0.33% C.	12	12	6
Tested, 0.33 to 0.41% C.	12	15	0
Hard (0.42 to 0.60% C.)	13	17	6
„ (0.61 to 0.85% C.)	14	7	6
„ (0.86 to 0.99% C.)	14	17	6
„ (1% C. and up)	15	7	6
Silico-manganese	16	5	0
Free-cutting	14	10	0
SIEMENS MARTIN ACID			
Up to 0.25% C.	15	15	0
Case-hardening	16	12	6
Silico-manganese	16	5	0

Billets, Blooms and Slabs for Forging and Stamping.

Basic soft, up to 0.25% C.	13	17	6
Basic hard, 0.41 to 0.60% C.	14	10	0
Acid, up to 0.25% C.	16	5	0

Other Semi-products, etc.

Tin bars	12	2	6
Sheet bars	12	2	6
*Wire rods, soft basic	17	7	6
„ hard basic	21	2	6
„ free-cutting	20	2	6
„ acid	24	13	6

* Subject to rebate.

FINISHED STEEL

Usual district deliveries.

[A rebate of 15/- per ton for steel bars, sections, plates, joists and hoops is obtainable in the home trade under certain conditions.]

	£	s.	d.
Plates, ship (N.E. Coast)	16	3	0
Boiler plts. (N.E. Coast)	17	0	6
Chequer plts. (N.E. Coast)	17	13	0
Angles, over 4 un. ins.	15	8	0
Tees, over 4 un. ins.	16	8	0
Joists, 3 in. × 3 in. and up	15	8	0
Rounds and squares, 3 in. to 5½ in.	16	8	0
Rounds under 3 in. to ⅜ in. (untested)	17	12	0
Flats—over 5 in. wide	15	13	0
„ 5 in. wide and under	17	12	0
Rails, heavy, f.o.t.	14	10	6
Hoops	18	7	0
Black sheets, 24 g. (4 t. lots)	22	15	0
Galv. cor. shts. („)	26	2	6
Galv. flat shts. („)	26	12	6
Galv. fencing wire, 8g. plain	26	17	6

FINISHED IRON

	£	s.	d.
CROWN IRON:			
England and Wales	15	12	6
Scotland	15	12	6
Ireland, f.o.q.	16	5	0
No. 3 BARS:			
England and Wales	12	10	0
Scotland	13	12	6
Ireland, f.o.q.	13	2	6
No. 4 BARS:			
England and Wales	13	0	0
Scotland	13	17	6
Ireland, f.o.q.	13	12	6
STRIP:			
England and Wales	—		
STAFFS MARKED BARS, f.o.t.	—		

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated, October 1, 1940.

	Dols.
No. 2 foundry, Phila.	24.84
No. 2 foundry, Valley	23.00
No. 2 foundry, Birm.	19.38
Basic, Valley	22.50
Malleable, Valley	23.00
Grey forge, Valley	22.50
Ferro-mang., seaboard	120.00
O.-h. rails, h'y, at mill	40.00
Billets	34.00
Sheet bars	34.00
	Cents
Iron bars, Chicago	2.25
Steel bars	2.15
Tank plates	2.10
Beams, etc.	2.10
Wire rods	2.00
Skelp, grooved steel	1.90
Steel strip	2.10
Steel sheets	2.10
Sheets, galv., 24 g.	3.50
Wire nails	2.55
Plain wire	2.60
Tinplates, 100-lb. box	$5.00

COKE (at ovens)

Welsh foundry	42/6 to 44/-
„ furnace	31/6 to 33/-
Durham foundry	39/6
„ furnace	33/5
Scottish foundry	42/6 to 47/6
„ furnace	31/- to 33/-

TINPLATES

f.o.b Bristol Channel ports

I.C. cokes	20 × 14 per box		30/9
„	28 × 20 „		61/6
„	20 × 10 „		—
„	18¾ × 14 „		—
C.W.	20 × 14 „		—
„	28 × 20 „		—
„	20 × 10 „		—
„	18¾ × 14 „		—

NON-FERROUS SCRAP

(Official Maximum Prices, per ton ex Works.)

	£	s.	d.
Bright untinned copper wire, in crucible form or in hanks	57	10	0
No. 1 copper wire	57	0	0
No. 2 copper wire	55	10	0
Copper firebox plates, cut up	57	10	0
Clear untinned copper, cut up	56	10	0
Braziery copper	53	10	0
Q.F. process and shell-case brass, 70/30 quality, free from primers	49	0	0
Clean fired 303 S.A. cartridge cases	47	0	0
70/30 turnings, clean and baled	43	0	0
Brass swarf, clean, free from iron and commercially dry	34	10	0
New brass rod ends, 60/40 quality	38	10	0
Hot stampings and fuse metal, 60/40 quality	38	10	0
Admiralty gunmetal, 88-10-2, containing not more than ¼ per cent. lead or 3 per cent. zinc, or less than 9½ per cent. tin	72	0	0

NEW BRASS TUBES, etc.

	Per lb.
Solid drawn tubes	13½d.
Brazed tubes	15½d.
Rods, drawn	11½d.
Rods, extd. or rlld.	8½d.
Sheets to 10 w.g.	10½d.
Wire	10½d.
Rolled metal	9½d.
Yellow metal rods	8½d.

COPPER TUBES, etc.

Solid drawn tubes	14½d.
Brazed tubes	14½d.
Wire	9½d.

PHOSPHOR BRONZE

	Per lb. basis
Strip	13½d.
Sheet to 10 w.g.	13½d.
Wire	15½d.
Rods	15½d.
Tubes	20½d.
Castings	17d.

Delivery 3 cwt. free.
10% phos. cop. £35 above B.S.
15% phos. cop. £40 above B.S.
Phosphor tin (5%) £40 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

AVERAGE MONTHLY PRICES OF STEEL RAILS

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1925	9 0 0	9 0 0	9 0 0	9 0 0	8 15 0	8 10 7½	8 10 0	8 10 0	8 10 0	8 4 9	8 0 0	8 0 0	8 11 7
1926	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 7 6	8 10 0	8 10 0	8 10 0	8 10 0	8 3 11
1927	8 10 0	8 10 0	8 10 0	8 2 6	8 2 6	8 2 6	8 2 6	8 2 6	8 2 6	8 3 9	8 5 0	8 5 0	8 4 10
1928	8 5 0	8 5 0	8 5 0	8 5 9	8 6 3	8 6 3	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 7 9½
1929	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0
1930	8 0 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0
1931	8 9 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 8
1932	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6
1933	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6
1934	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6
1935	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6
1936	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6	8 7 6
1937	8 7 6	8 7 6	8 7 6	8 7 6	10 2 6	10 2 6	10 2 6	10 2 6	10 2 6	10 2 6	10 2 6	10 2 6	9 10 10
1938	10 2 6	10 2 6	10 2 6	10 2 6	10 2 6	10 2 6	10 2 6	10 2 6	10 2 6	10 2 6	10 2 6	10 2 6	10 2 6
1939	9 10 0	9 10 0	9 10 0	9 10 0	9 10 0	9 10 0	9 10 0	9 10 0	9 3 0	9 3 0	10 3 0	10 3 0	9 11 0
1940	10 3 0	11 3 0	11 3 0	11 3 0	11 3 0	11 3 0	12 15 6	12 15 6	12 15 6	12 15 6	—	—	—

AVERAGE MONTHLY PRICES OF EAST COAST HEMATITE MIXED NUMBERS AT MIDDLESBROUGH*

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
1925	87 5	85 9	84 7½	82 6	80 10½	79 3	77 1½	75 7½	75 0	74 3½	74 9	76 0	79 5½
1926	77 3	77 9	77 3½	76 3	77 4½	78 0	79 8½	81 9	83 4½	87 7½	92 6	90 8½	81 7½
1927	90 0	90 0	86 3½	83 1½	80 6	78 0	76 6	75 4½	75 0	72 9	71 9	71 1½	79 2½
1928	69 7½	69 7½	69 9	70 0	70 0	69 3	68 7½	69 2	70 0	70 0	70 3	71 0	69 9½
1929	71 6	72 0	73 6	74 0	74 0	74 1½	74 9	75 6	76 1½	76 8½	78 1½	79 0	74 1½
1930	78 2½	78 0	76 9	75 0	74 0	72 7½	71 0	71 0	71 0	71 0	70 10½	70 4½	73 3½
1931	70 0	69 0	68 0	66 8½	65 1½	63 4½	62 9	61 1½	65 0	65 0	65 0	65 0	65 6
1932	64 10	64 3	63 6	63 6	63 6	62 7½	62 0	60 6	60 0	59 3	59 0	59 0	61 10
1933	59 0	59 0	59 0	59 0	59 0	59 0	59 0	59 0	59 3	60 7½	62 6	62 6	59 8½
1934	62 6	65 0	67 6	67 6	67 6	67 6	67 6	67 6	68 0	68 6	68 6	68 6	67 2
1935	68 6	68 6	68 6	68 6	68 6	68 6	69 7½	70 6	70 6	70 6	70 6	70 6	69 5½
1936	70 6	75 3	76 6	76 6	77 4	80 0	85 0	85 0	85 0	85 0	85 0	85 0	80 6
1937	97 6	97 6	97 6	97 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	122 6	114 2
1938	132 6	132 6	132 6	132 6	132 6	132 6	132 6	132 6	132 6	132 6	132 6	132 6	132 6
1939	120 0	120 0	120 0	120 0	120 0	120 0	115 0	115 0	115 0	115 0	124 0	124 0	119 0
1940	124 0	127 0	127 0	127 0	127 0	127 0	130 6	130 6	130 6	—	—	—	—

* Since March, 1934, delivered works; previously f.o.t. furnaces. NOTE.—Prices of hematite have since July 1, 1936, been subject to a rebate of 5s. under certain conditions.

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WORKS CHEMIST Wanted for Non-Ferrous Foundry, North-East Coast. State age, experience and salary expected.—Box 550, Offices of THE FOUNDRY TRADE JOURNAL, 3, Amersham Road, High Wycombe.

WANTED for one of the largest steel foundries in the country, a General Foreman to take charge of all moulding and coremaking. State age, education, experience and salary required to Box 464, Offices of THE FOUNDRY TRADE JOURNAL, 3, Amersham Road, High Wycombe.

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Correspondence should be addressed to the General Secretary, Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester, from whom full particulars can be obtained of this service.

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FOR IMMEDIATE DISPOSAL, Works Premises at Union Street, Rotherham, previously used as Iron Foundry. Area approximately 13,000 square feet, with buildings about 10,000 square feet. Private Sidings and main road access. Wired throughout Rotherham Corporation Electricity. Corporation Gas available. Main buildings 130 feet long, 25 feet wide, 21 feet high (13 feet to eaves); 2 ton travelling crane. Land leasehold (the usual railway lease). Price £2,300, or nearest offer. Possession on completion.—Apply Box 530, Offices of THE FOUNDRY TRADE JOURNAL, 3, Amersham Road, High Wycombe.

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